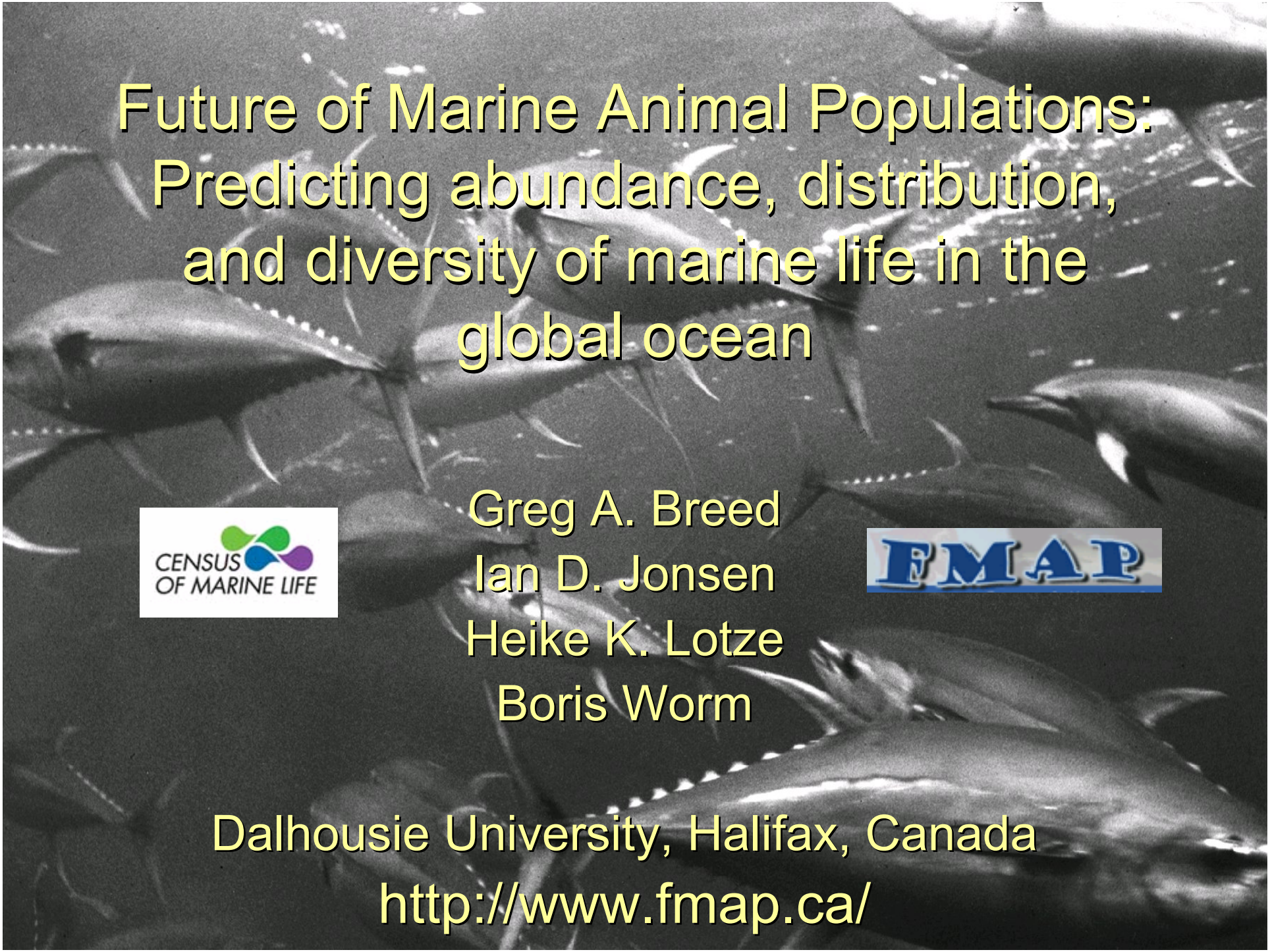
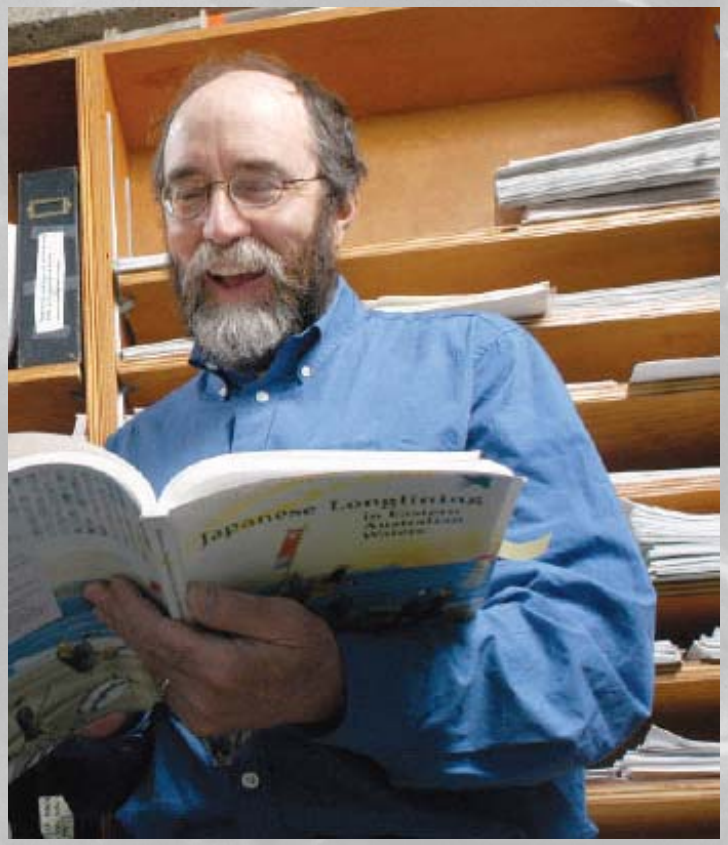


Future of Marine Animal Populations: Predicting abundance, distribution, and diversity of marine life in the global ocean

Greg A. Breed
Ian D. Jonsen
Heike K. Lotze
Boris Worm

Dalhousie University, Halifax, Canada
http://www.fmap.ca/

Ransom Aldrich Myers (RAM)



Current FMAP projects

1

Synthesize patterns of global ocean diversity

Deep sea, plankton, top predators…

Boris Worm &
Heike Lotz

2

Predict future marine biodiversity

Effect of long term changes on ecosystem structure and function

Boris Worm &
Heike Lotz

3

Develop statistical methods for complex ecological data

Focusing on telemetry data

Ian Jonsen

Part 1: FMAP projects 1 & 2 overview and results

Part 2: Analysis of marine animal tagging data

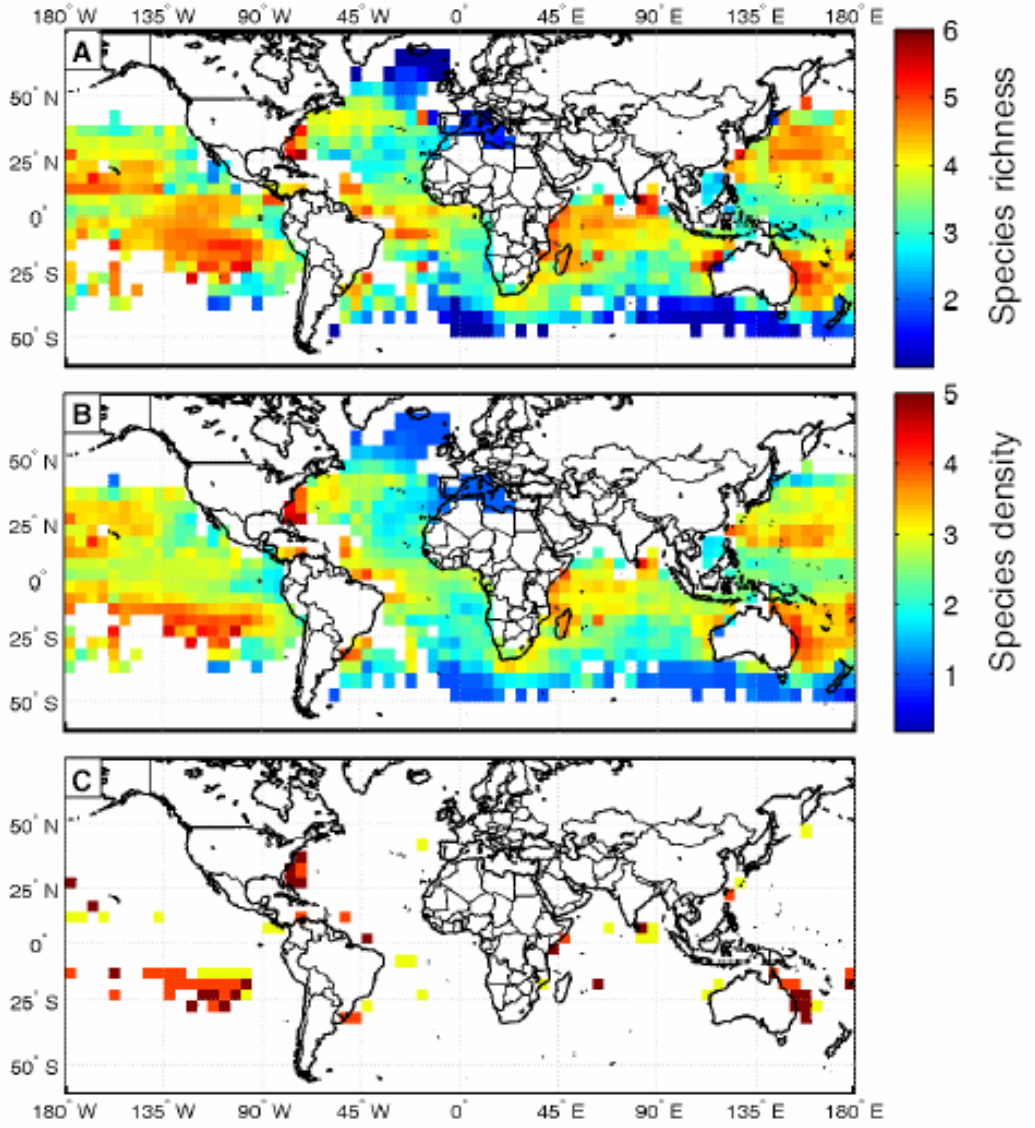
Part 1

FMAP diversity projects overview

Predator diversity in the open oceans

(1) Synthesize patterns of global ocean diversity
(2) Predict future marine biodiversity

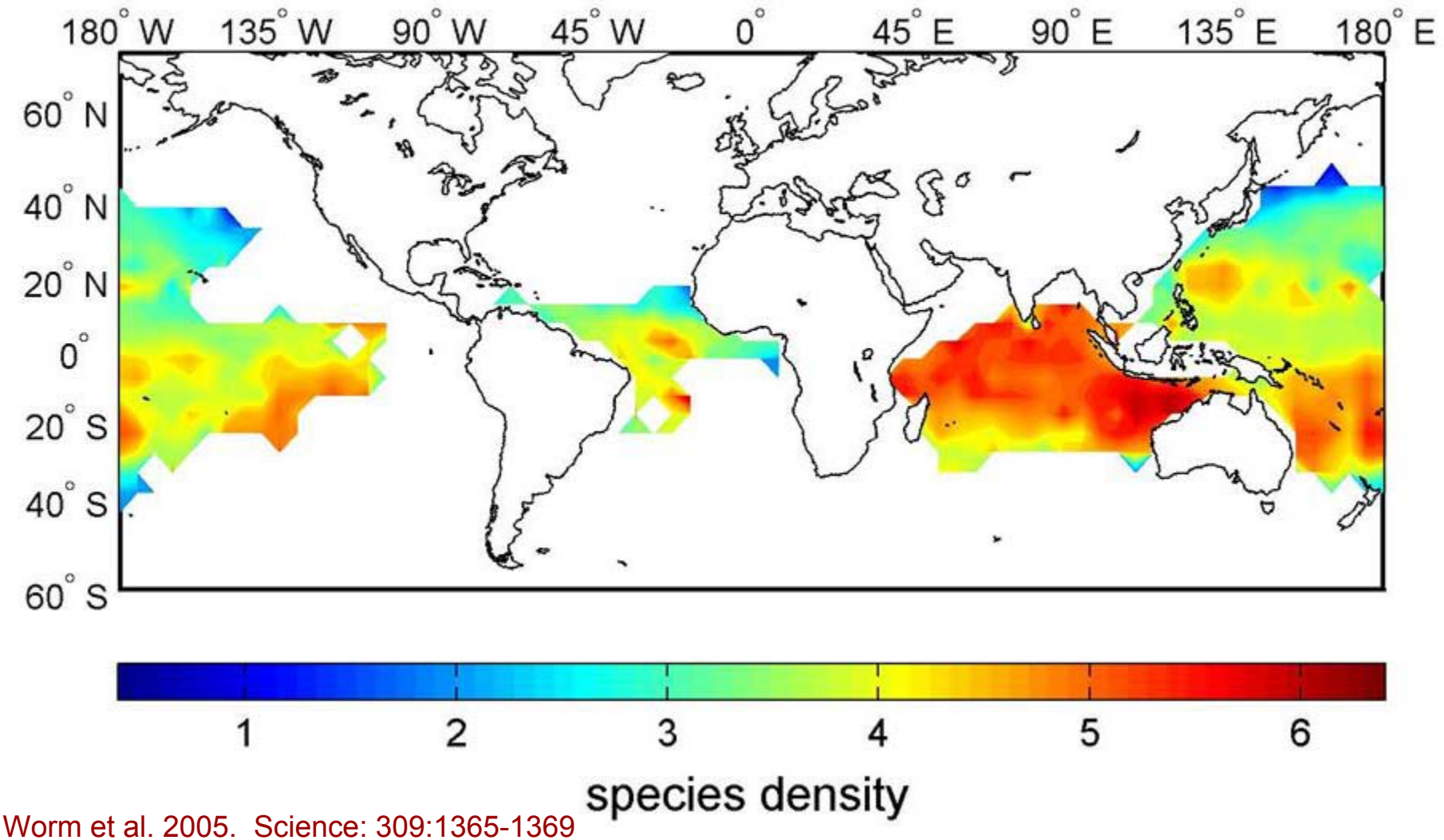
- Tuna and billfish
- Consistent patterns of sp. richness and density
- Peaks at intermediate latitude
- Five major hotspots:
  - U.S. east coast
  - Hawaiian chain
  - Southeast Pacific
  - Australian east coast
  - Sri Lanka



Worm et al. 2005. Science 309:1365-1369

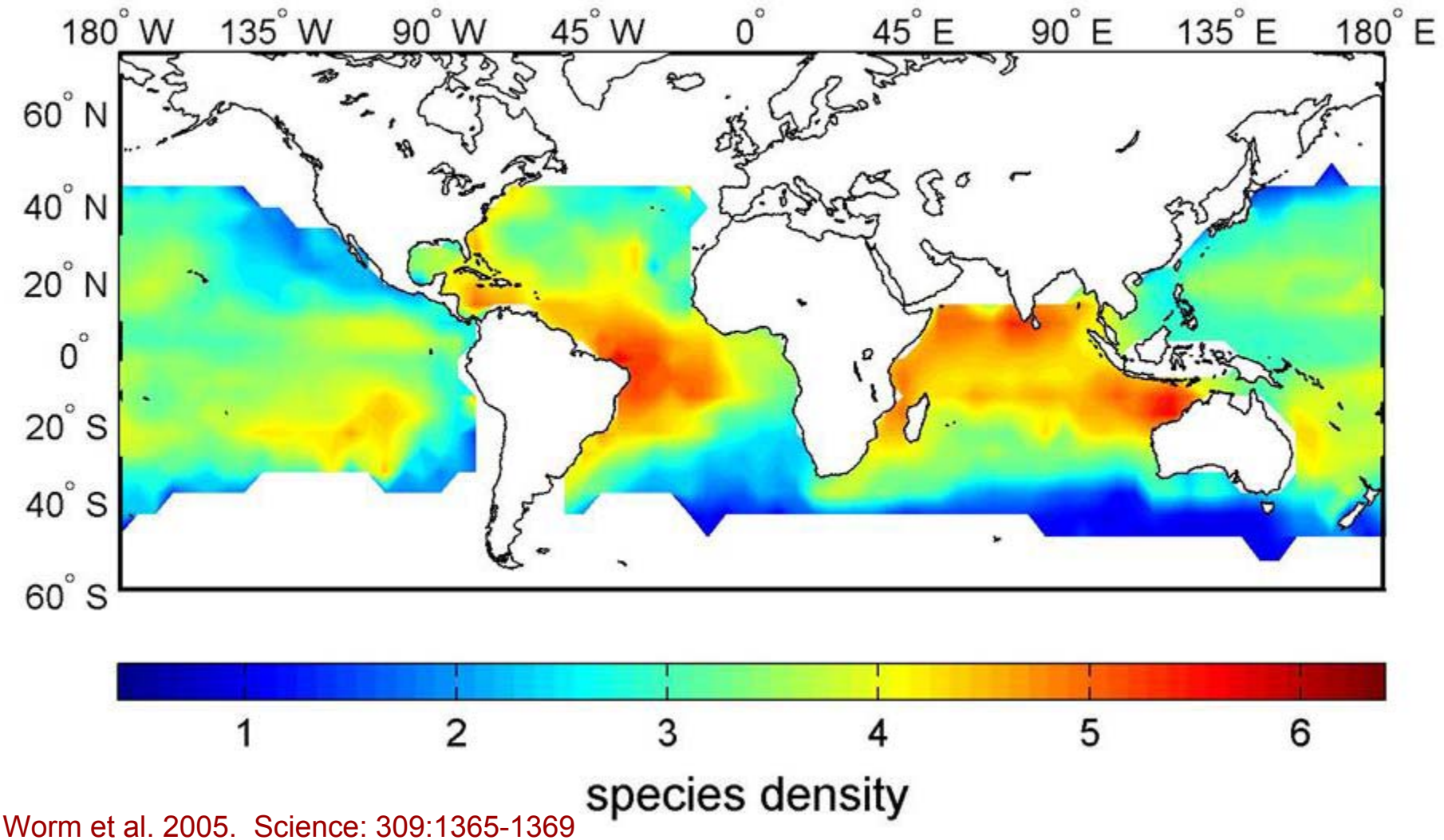
Temporal trends last 50 years

1950s



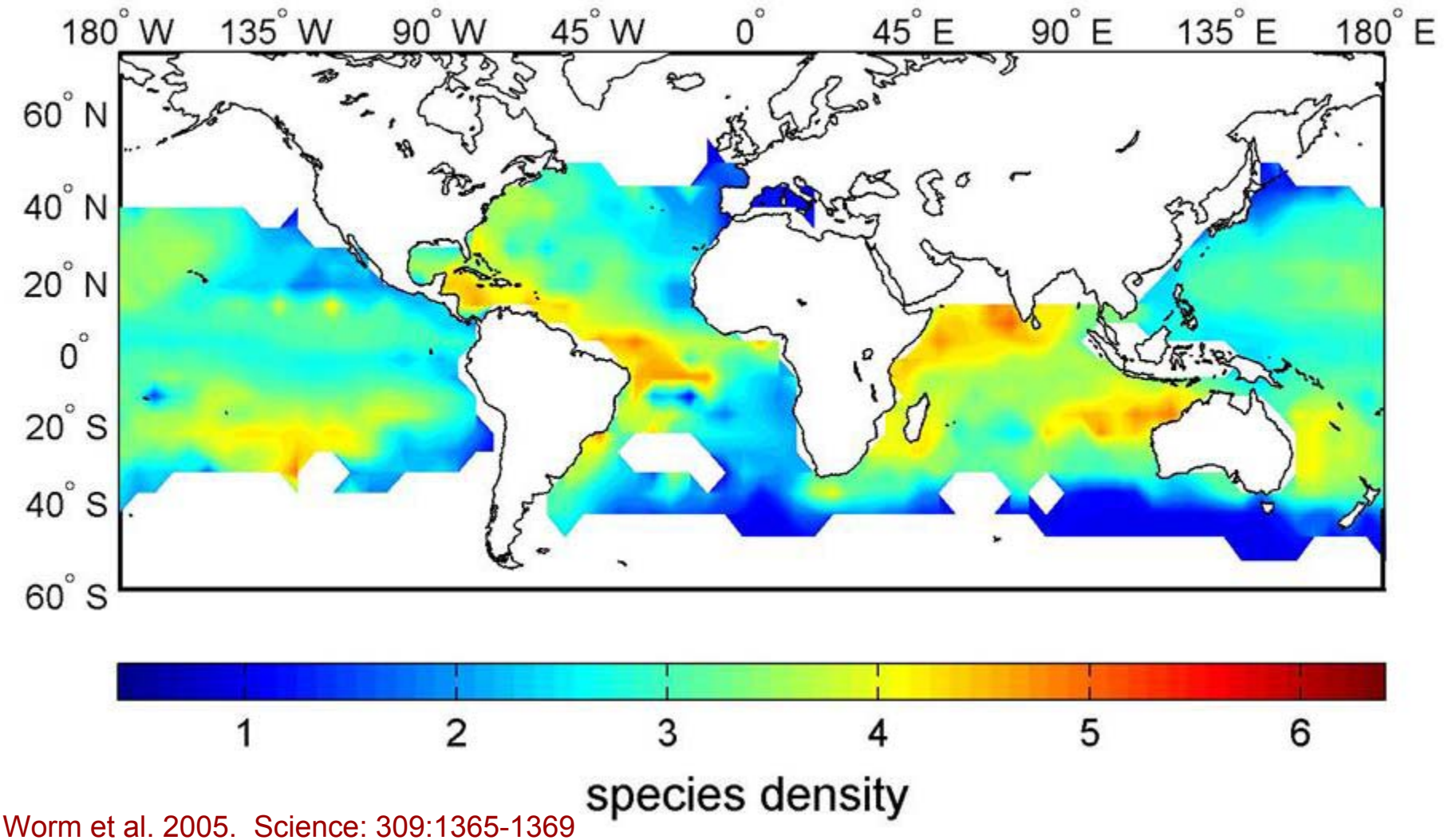
Worm et al. 2005. Science: 309:1365-1369

1960s



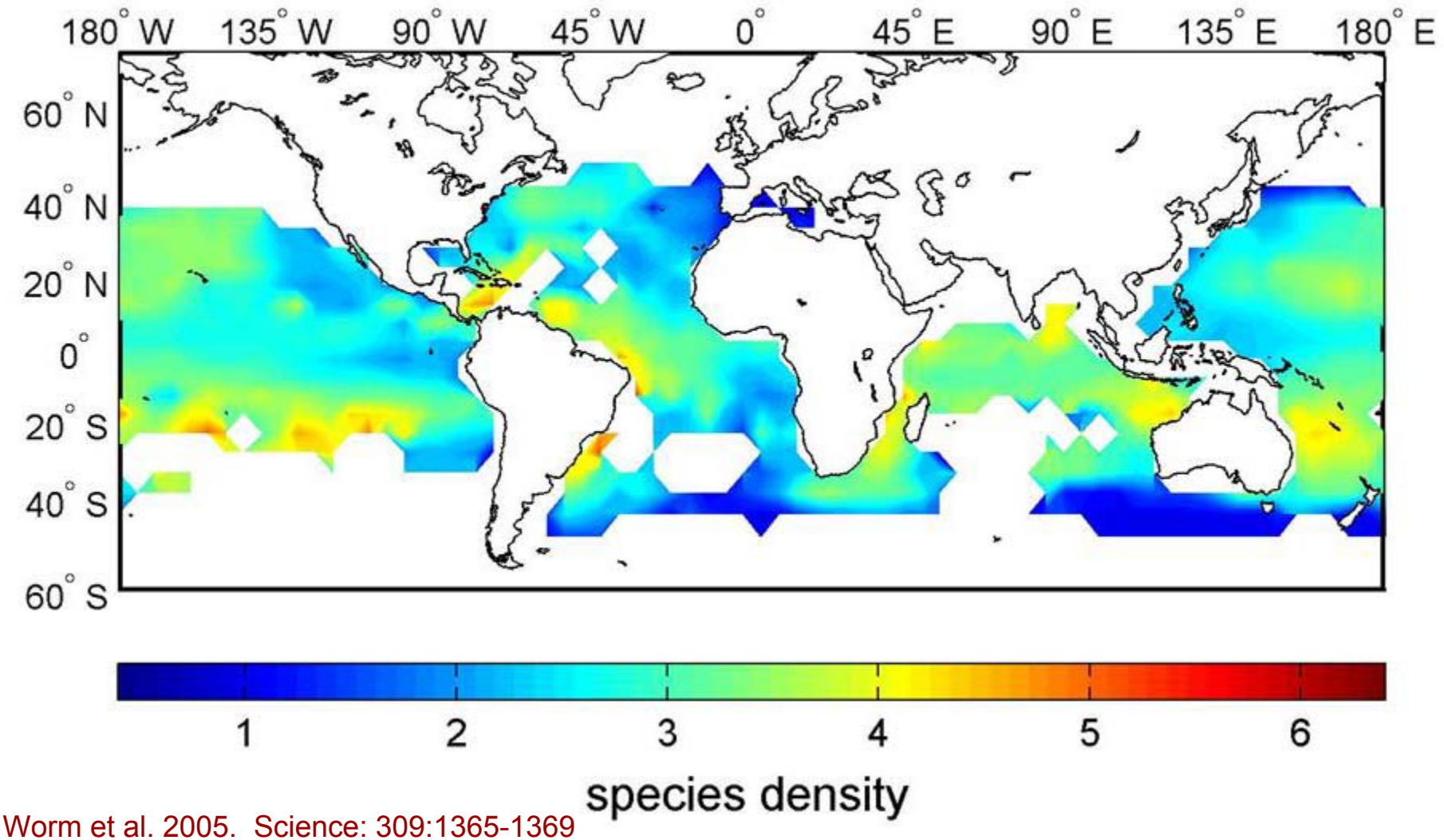
Worm et al. 2005. Science: 309:1365-1369

1970s



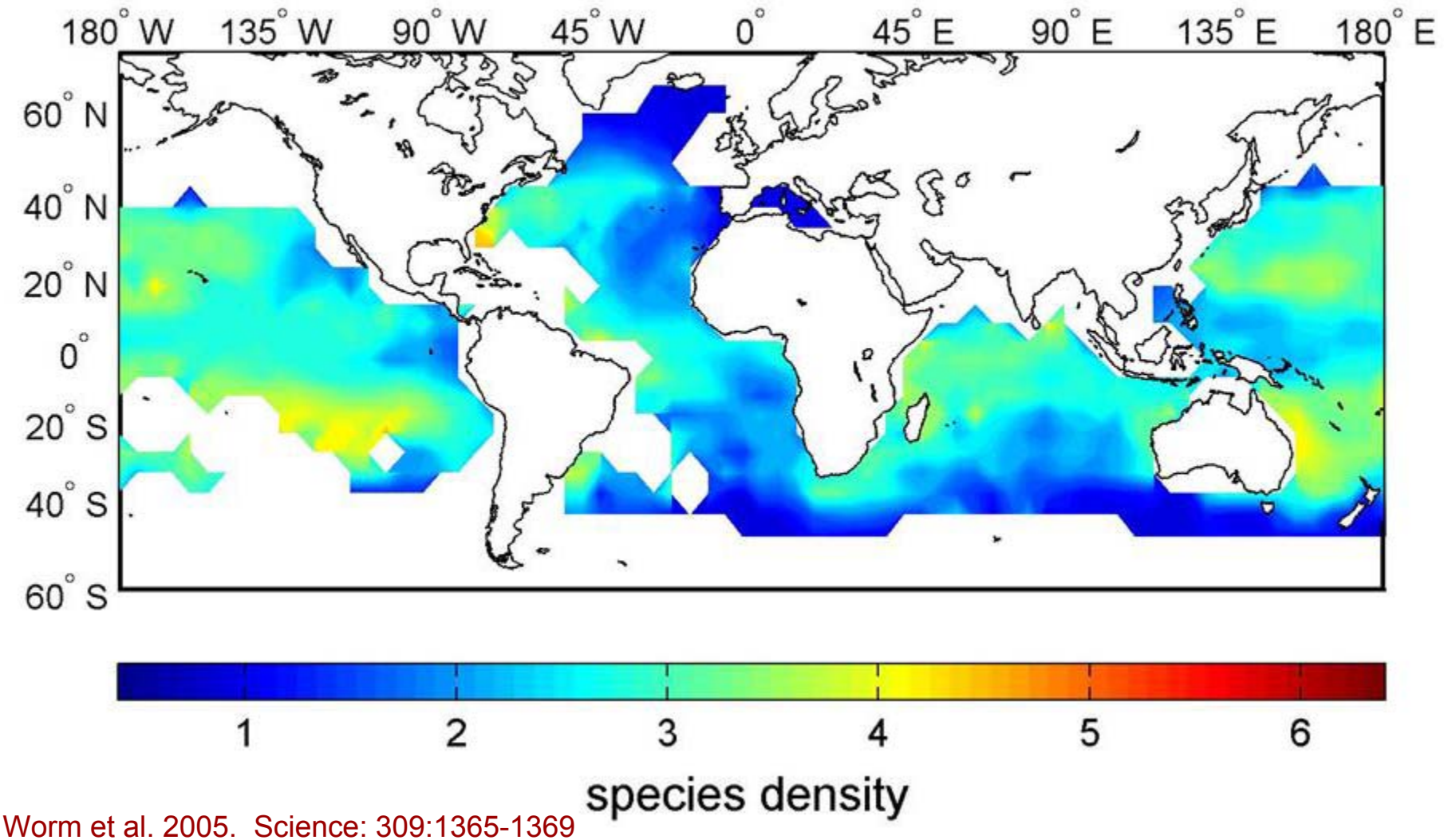
Worm et al. 2005. Science: 309:1365-1369

1980s



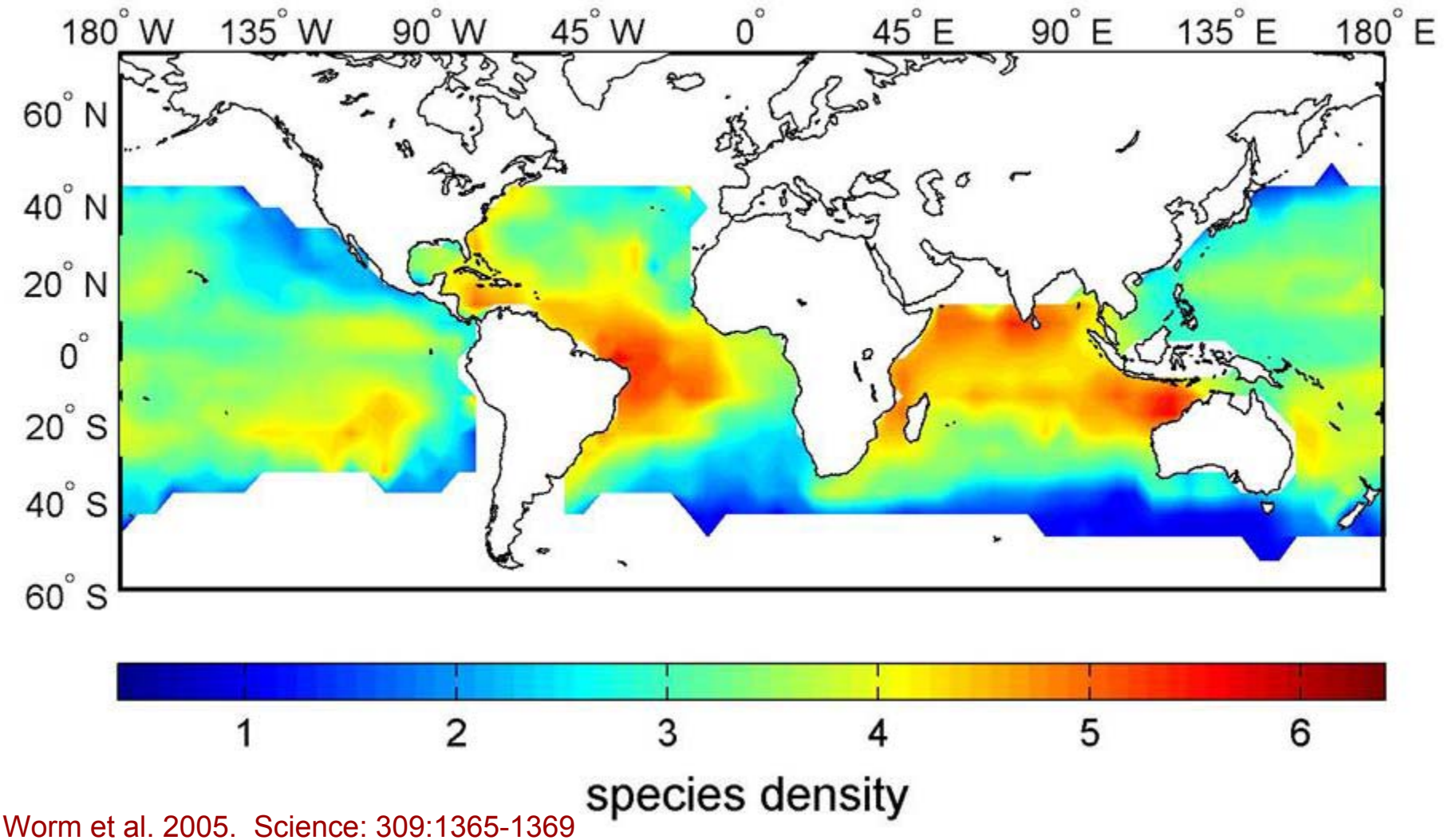
Worm et al. 2005. Science: 309:1365-1369

1990s



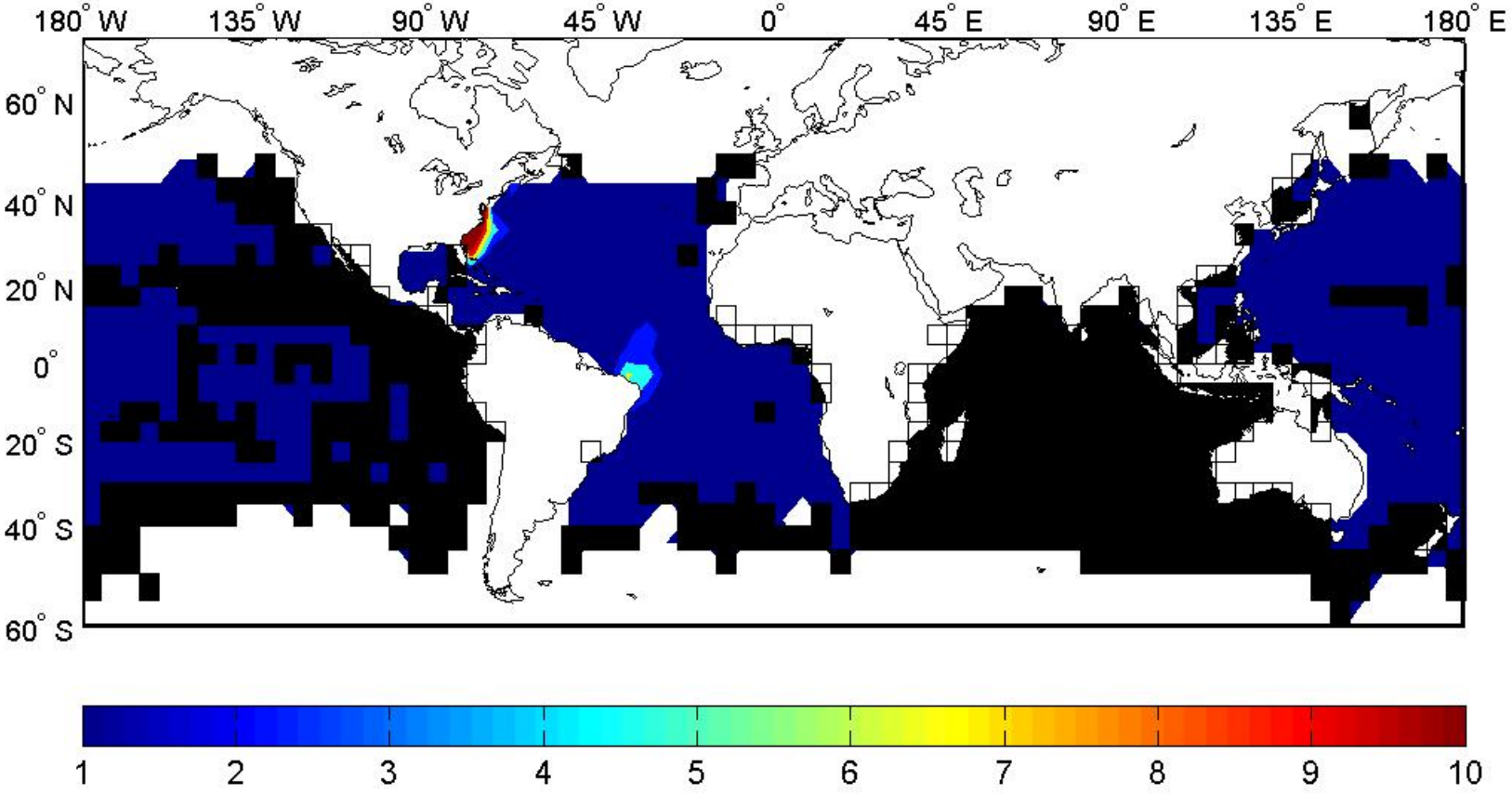
Worm et al. 2005. Science: 309:1365-1369

1960s

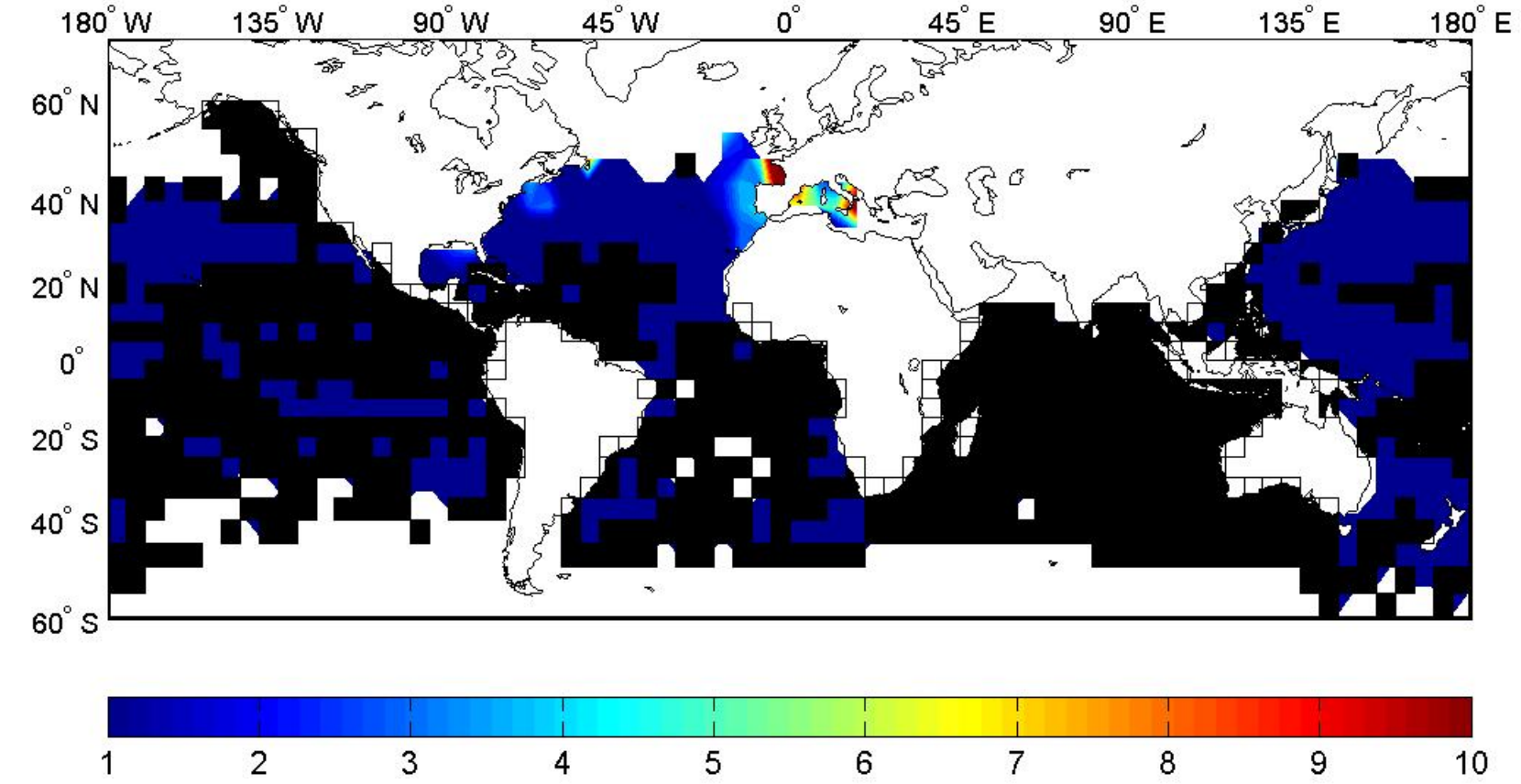


Worm et al. 2005. Science: 309:1365-1369

Bluefin tuna example

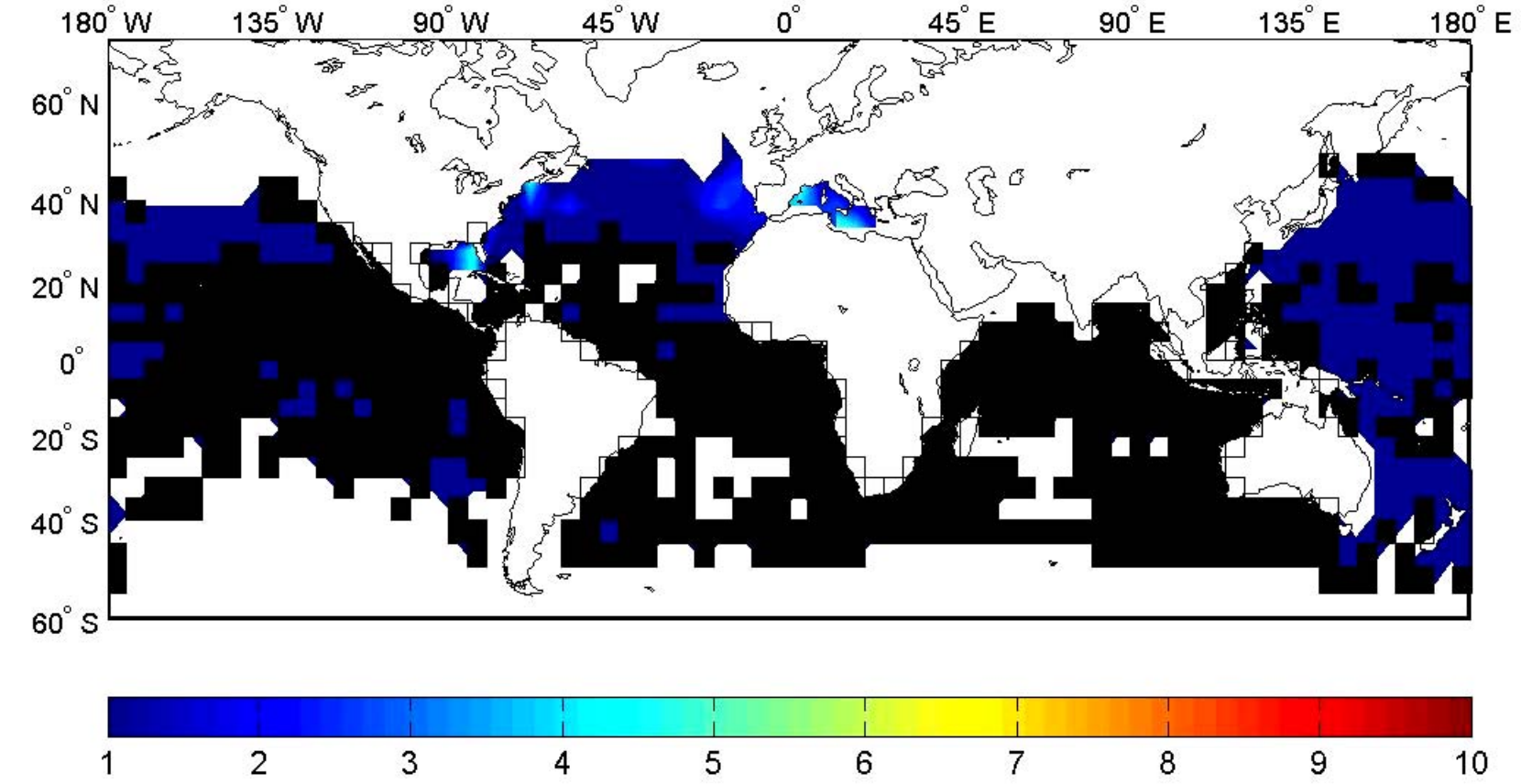


Source: Tittensor & Worm, unpublished



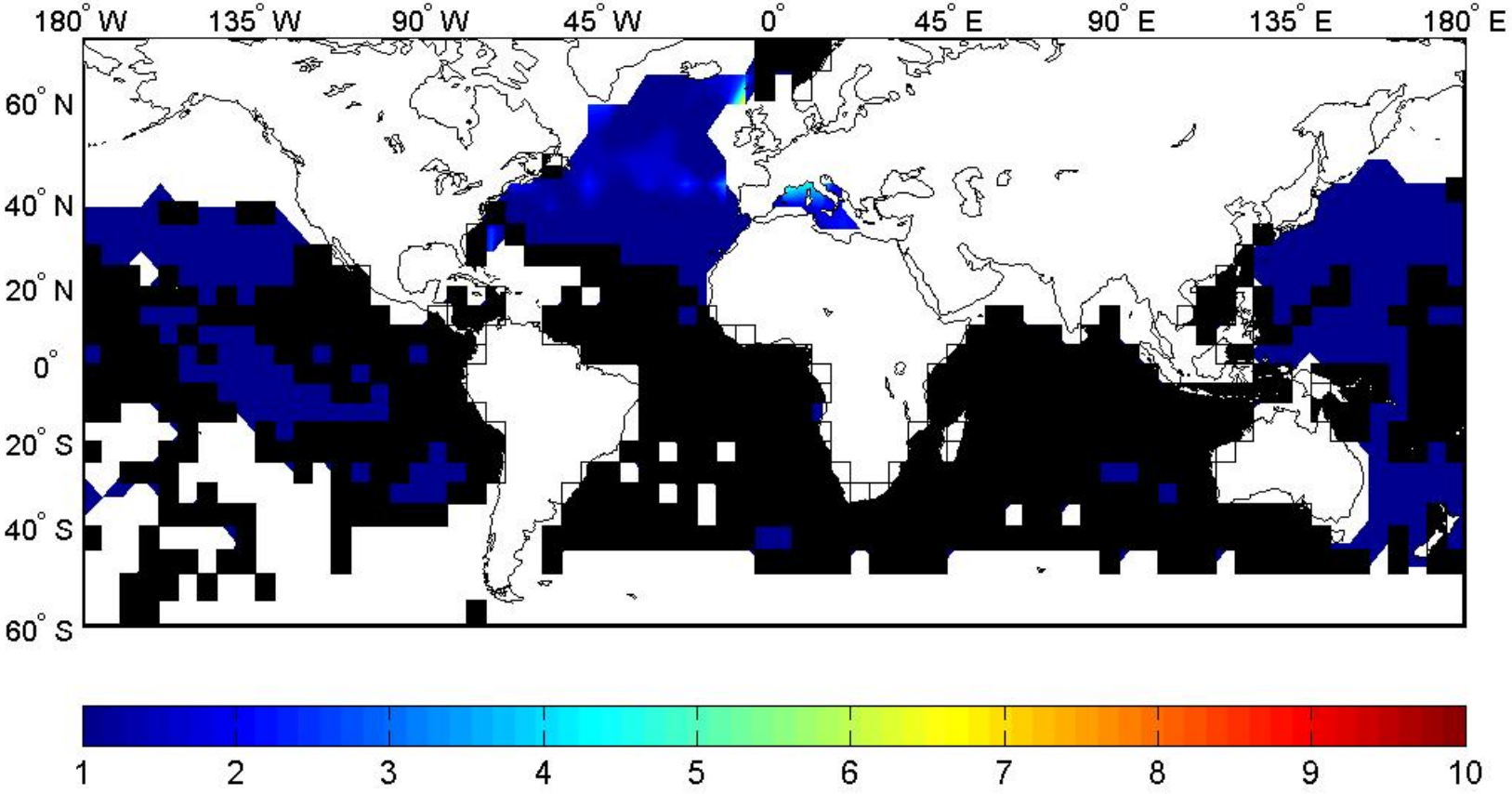
Bluefin Tuna / 1000 hooks 1970

Source: Tittensor & Worm, unpublished



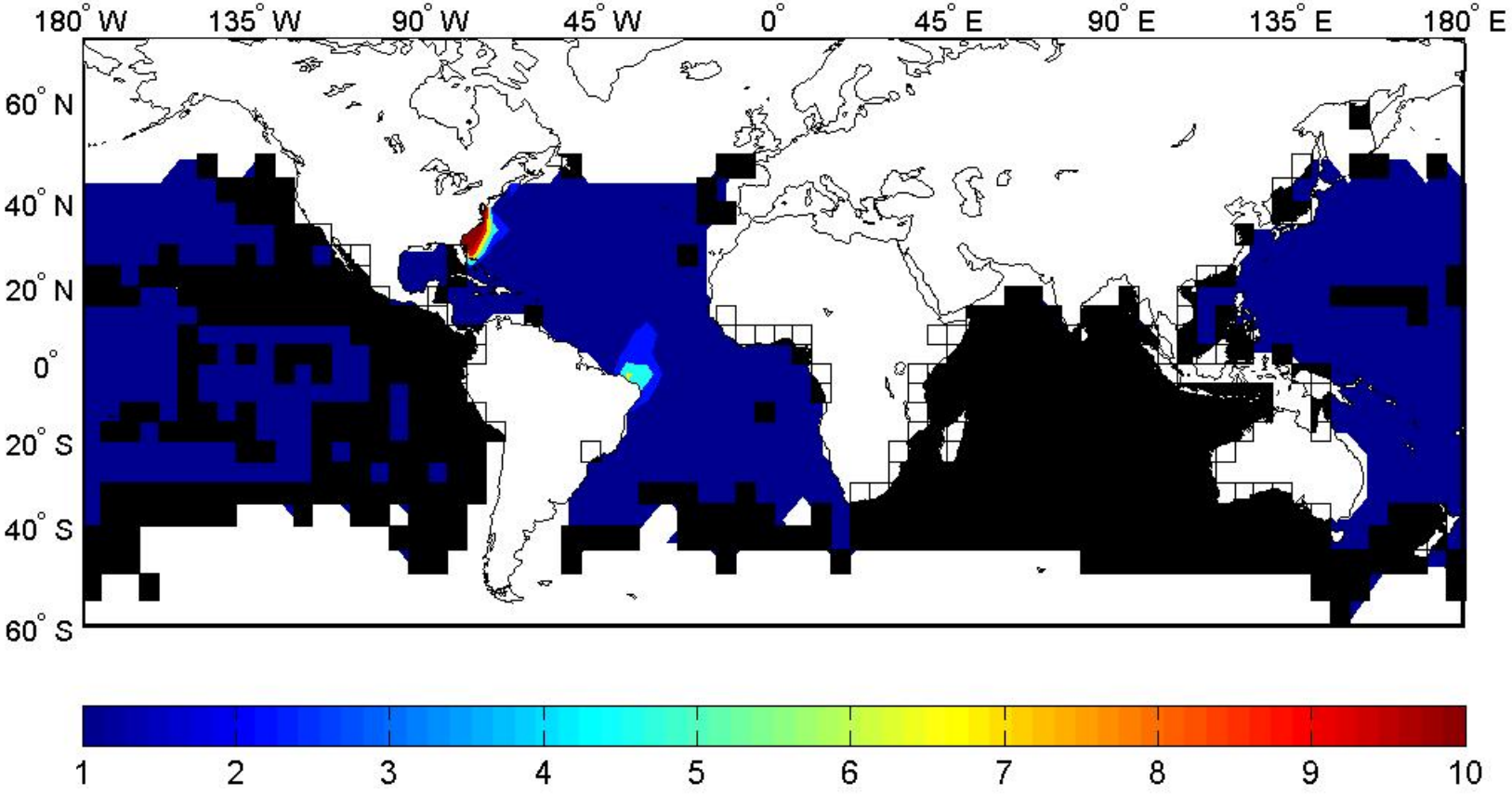
Bluefin Tuna / 1000 hooks 1980

Source: Tittensor & Worm, unpublished



Bluefin Tuna / 1000 hooks 1990

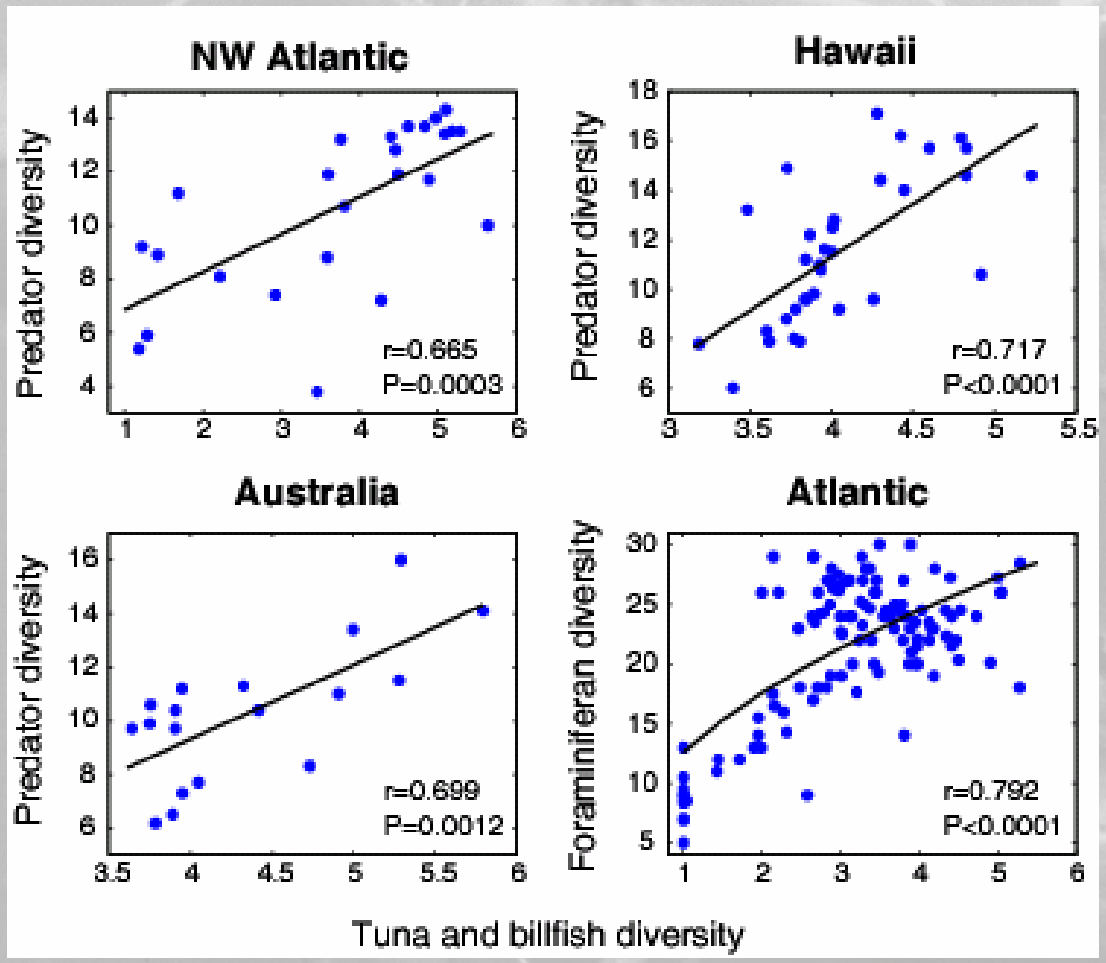
Source: Tittensor & Worm, unpublished



Bluefin Tuna / 1000 hooks 1960

Source: Tittensor & Worm, unpublished

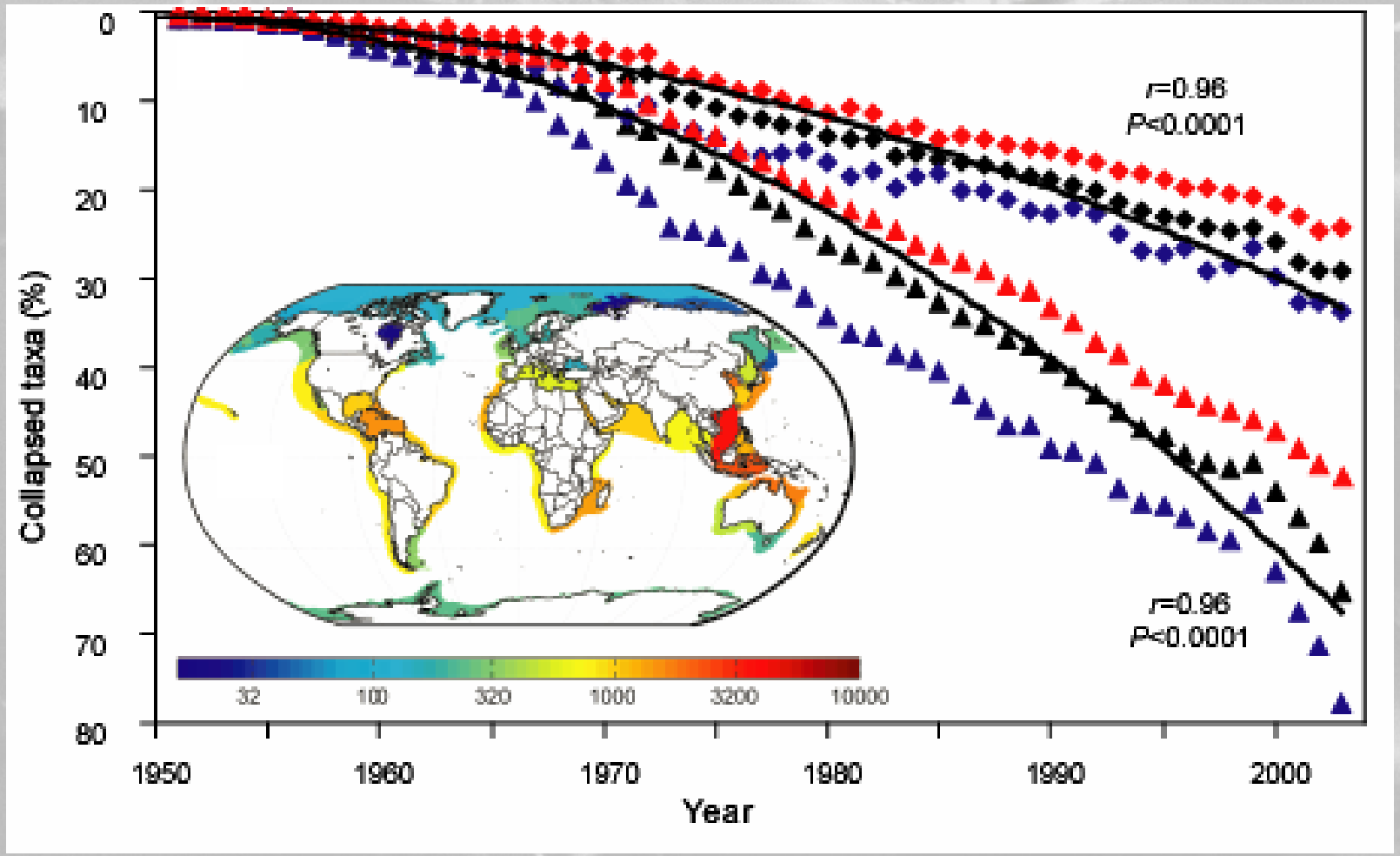
Tuna and Billfish diversity highly correlated with overall diversity



Worm et al. 2005. Science: 309:1365-1369

State of World fisheries

(1) Synthesize patterns of global ocean diversity
(2) Predict future marine biodiversity

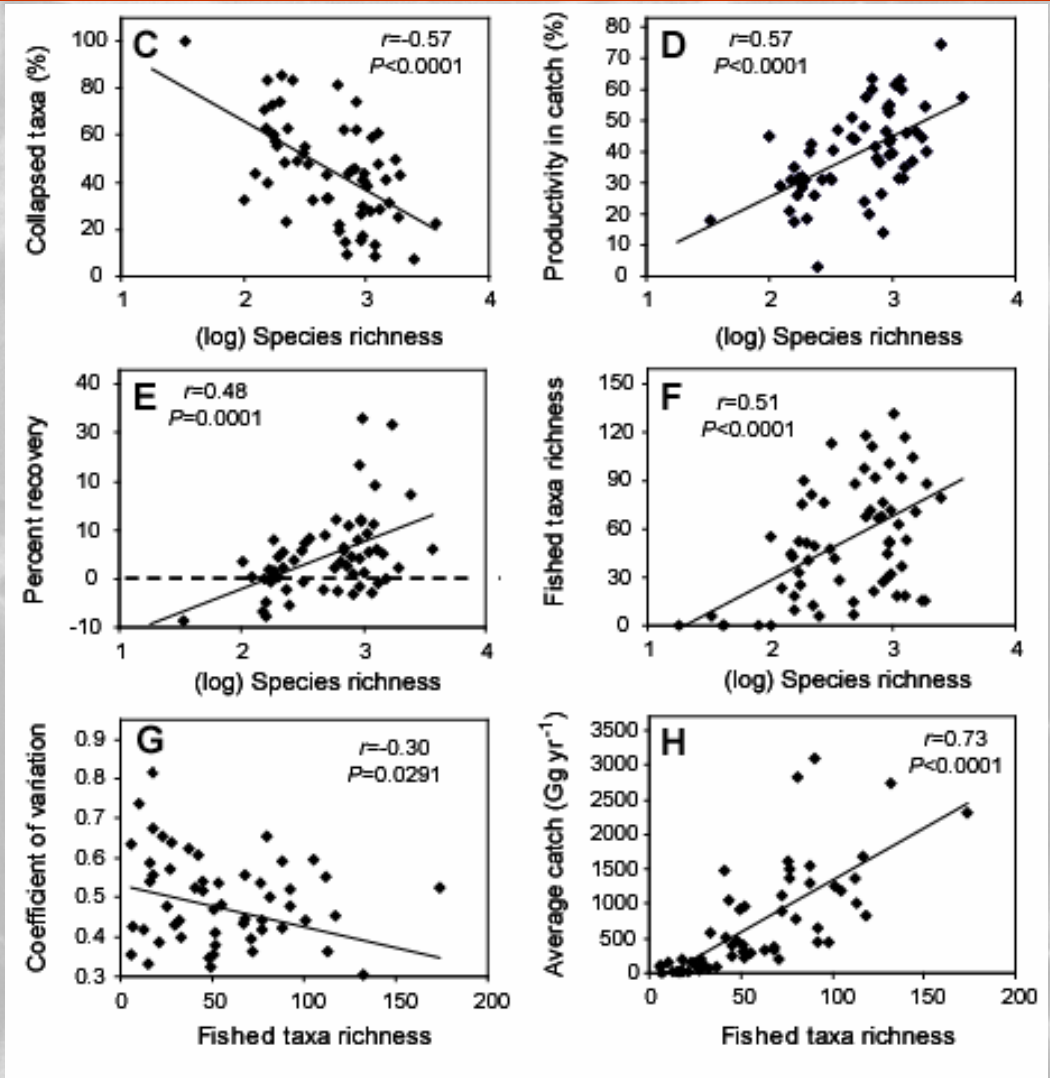


Source: Worm et al. 2006. Science 314:787-790

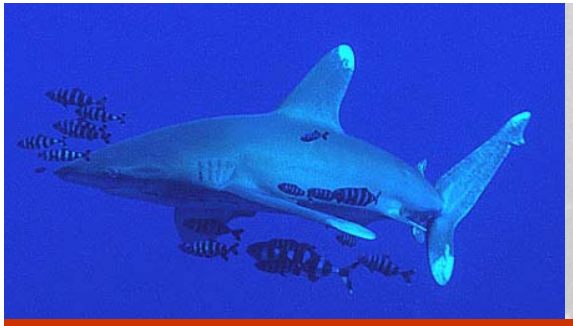
Biodiversity begets fisheries sustainability

More species →

- Fewer collapses
- Faster recovery
- More predictable
- More productive



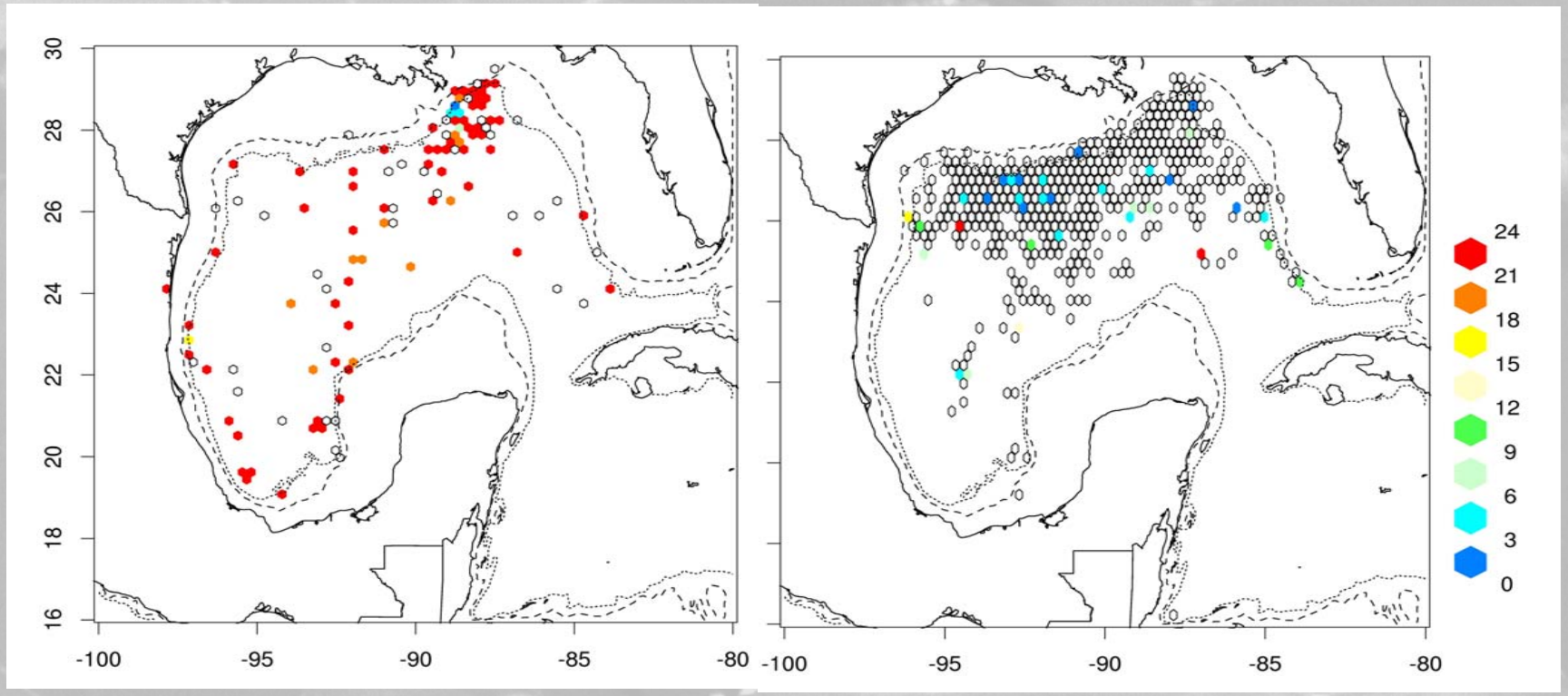
Source: Worm et al. 2006. Science 314:787-790



Global shark assessment

(1) Synthesize patterns of global ocean diversity
(2) Predict future marine biodiversity

300-fold decline of sharks in the Gulf of Mexico

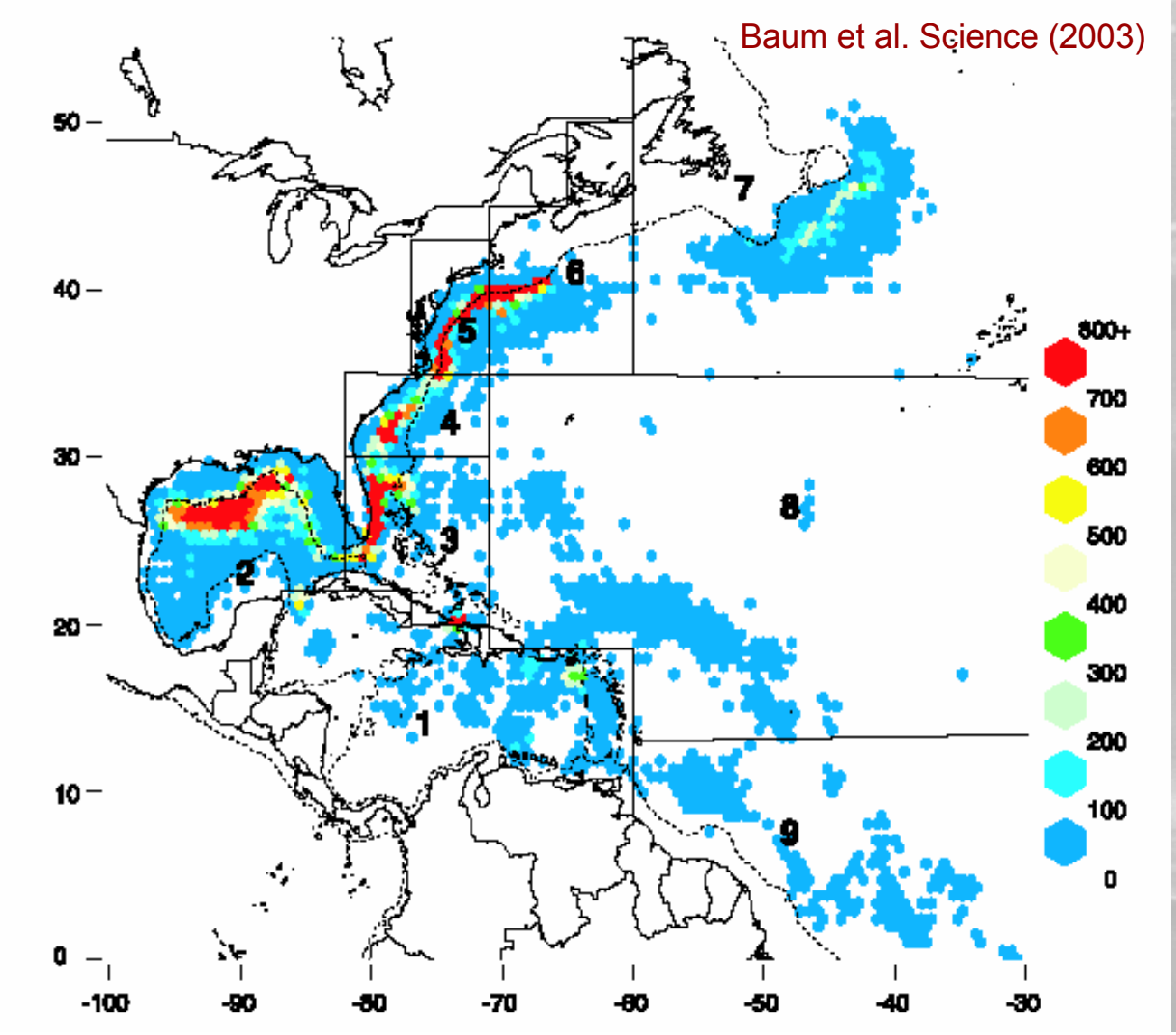


1950's 1990's

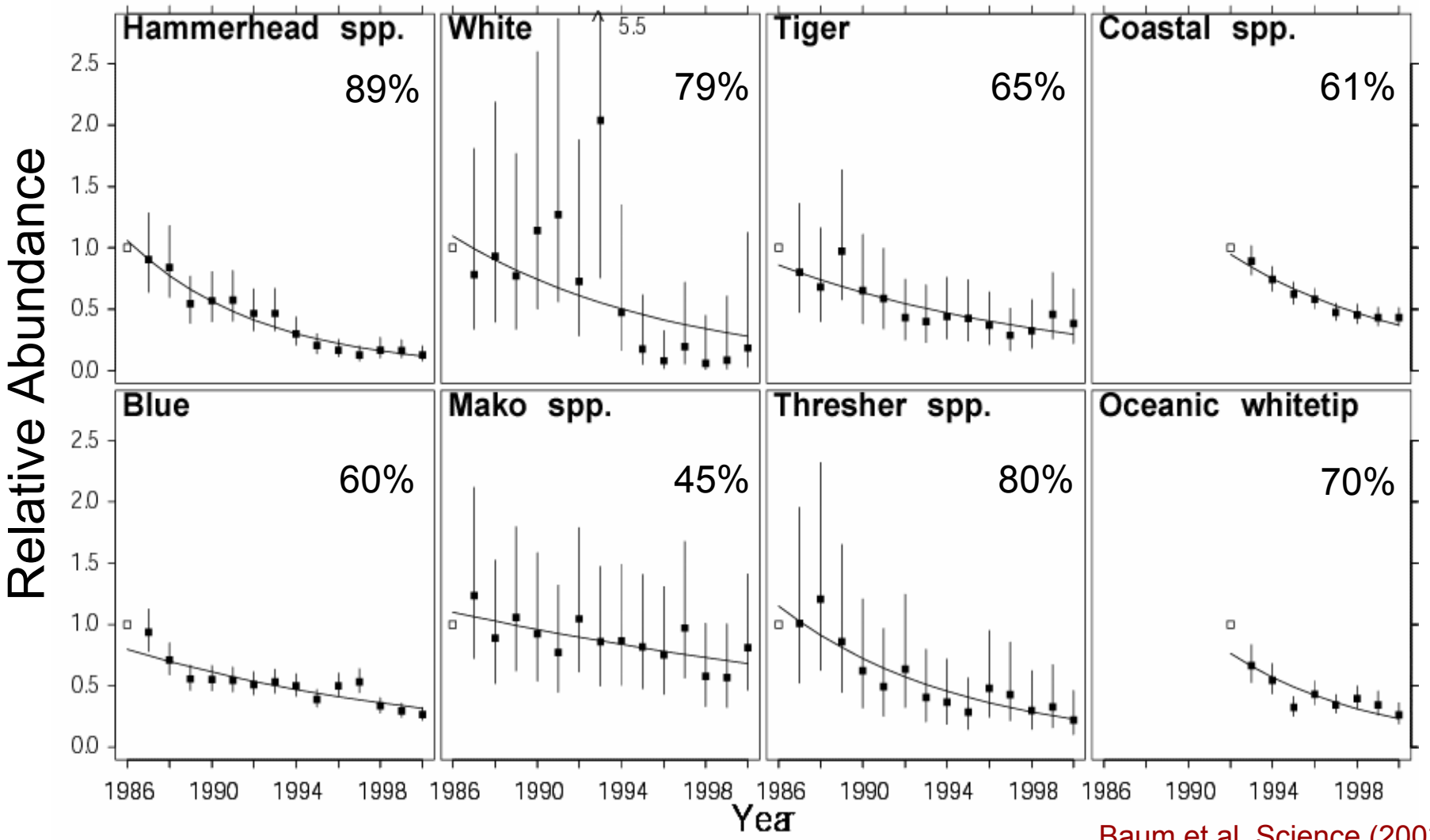
Oceanic Whitetip captures per 10,000 hooks

Baum, Myers. Ecol. Letters (2004)

Pelagic U.S. longline fishing effort
NW Atlantic 1986-2000

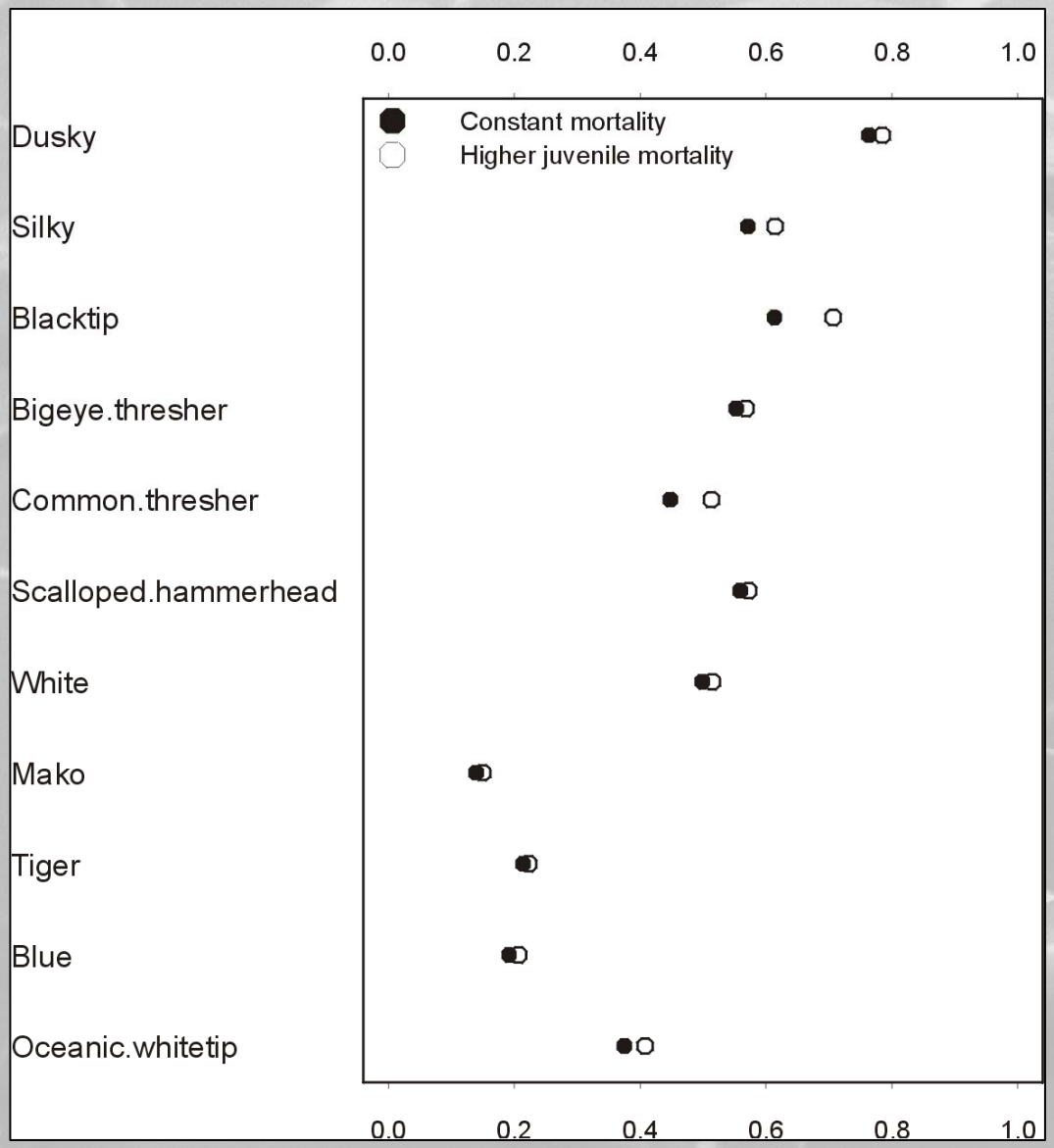


Decline of sharks in NW Atlantic



Baum et al. Science (2003)

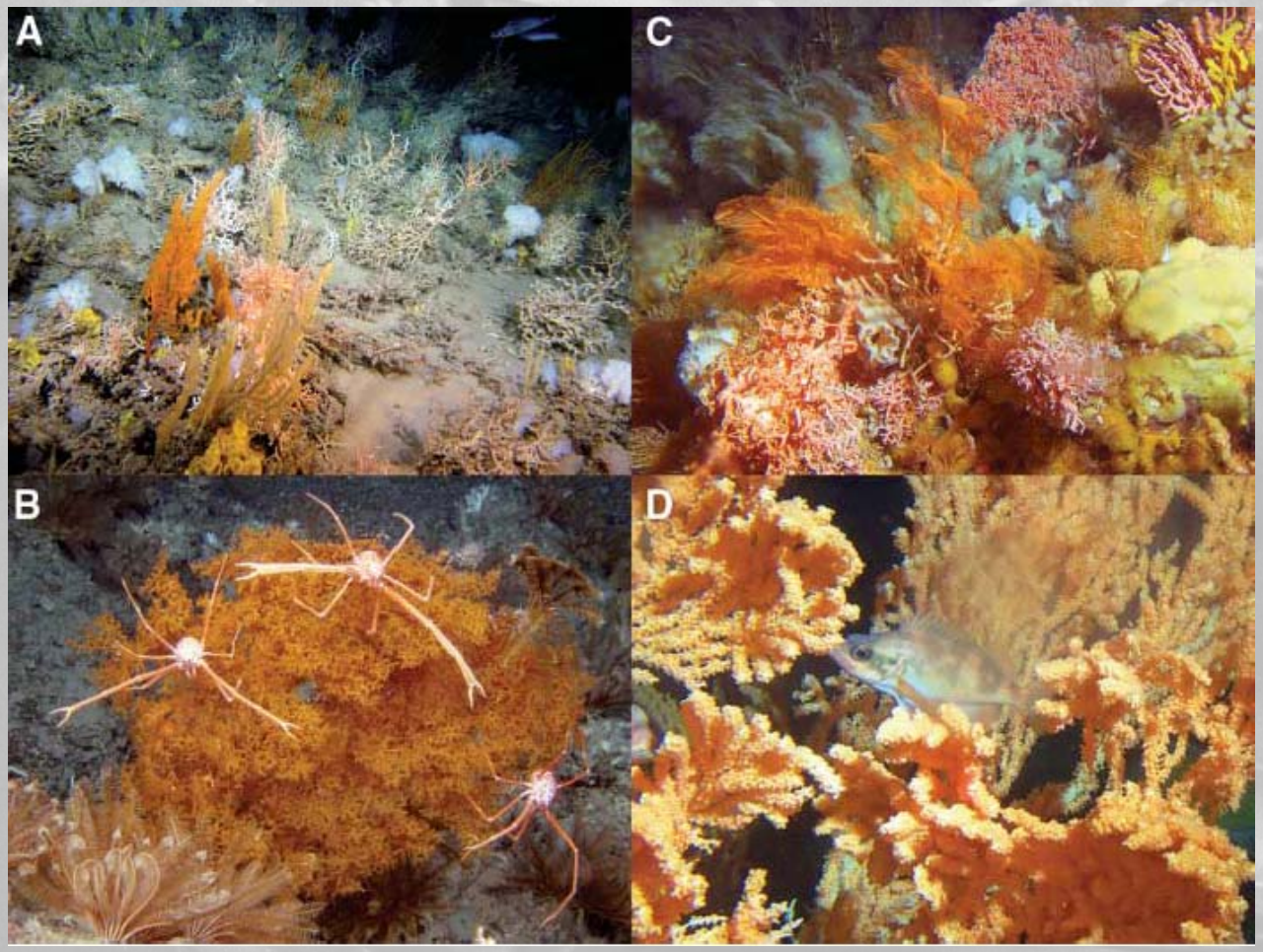
Proportional reduction in current fishing mortality needed to ensure survival of shark populations



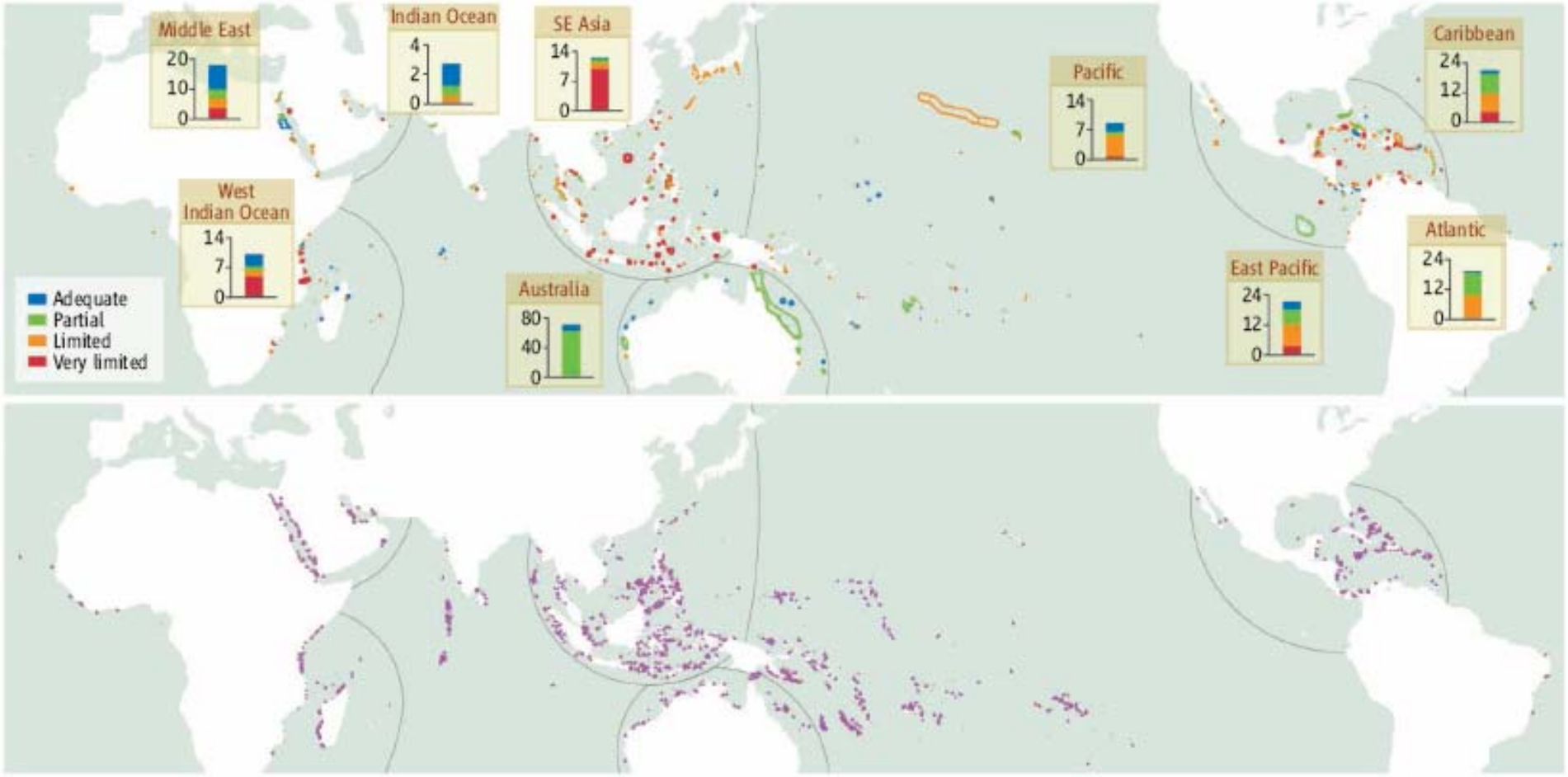
Myers & Worm, Phil. Trans. (2005)

State of Coral Reefs

(1) Synthesize patterns of global ocean diversity
(2) Predict future marine biodiversity



Effectiveness of Reef MPAs

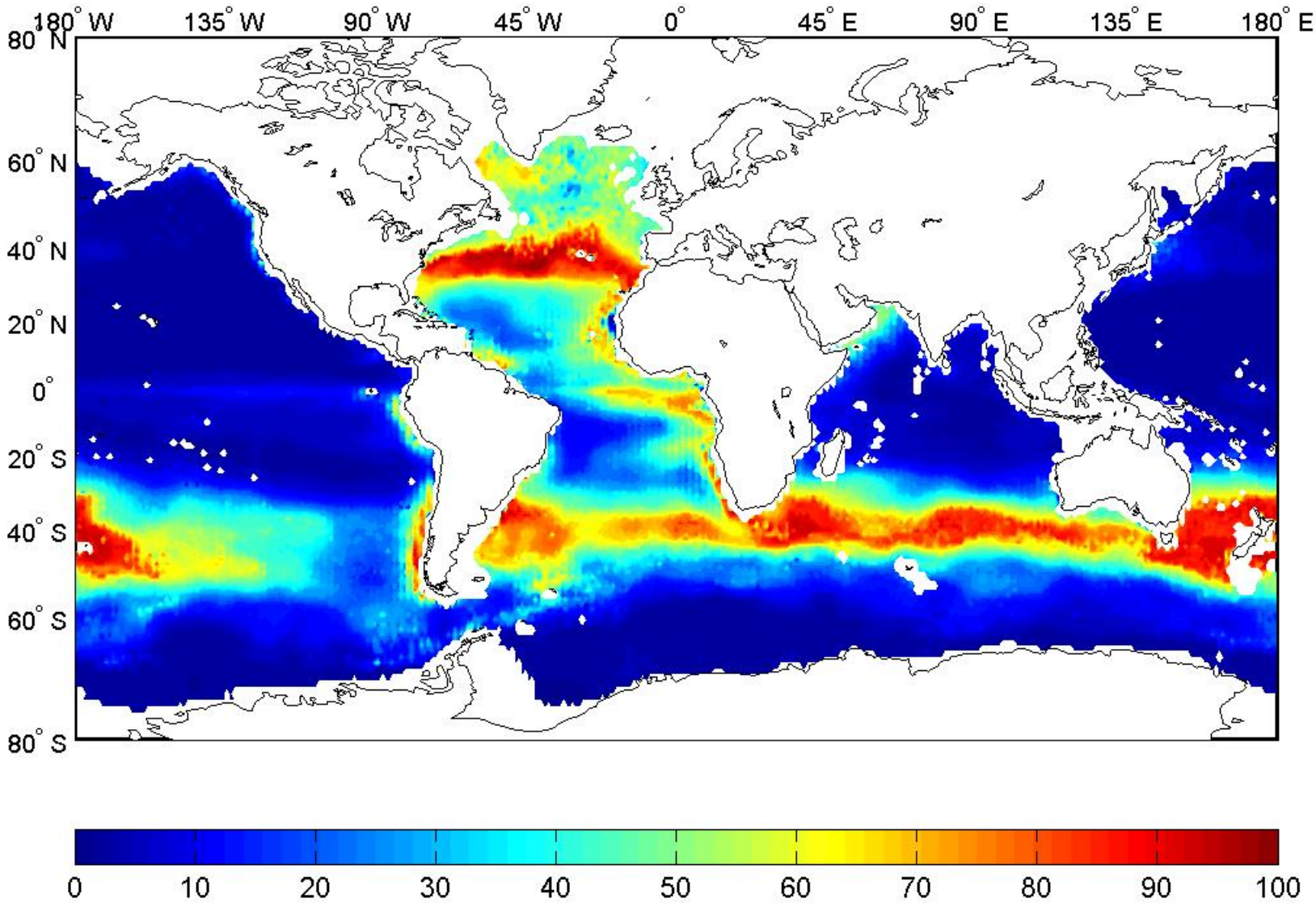


Conservation of MPAs. (Top) Status of the global network. Location and shape of all 980 MPAs are shown. Categorization of MPAs was based on the average of the attributes analyzed (*9*). The percent of coral reefs per region covered by MPAs in those categories is shown on the bar charts. **(Bottom)** MPAs needed for an optimum coverage of the world's coral reefs. Dots represent MPAs of 10 km^2 and spaced at 15 km from each other.

Mora et al. 2006, Science 312:1750-1751

Tittensor et al. Unpublished

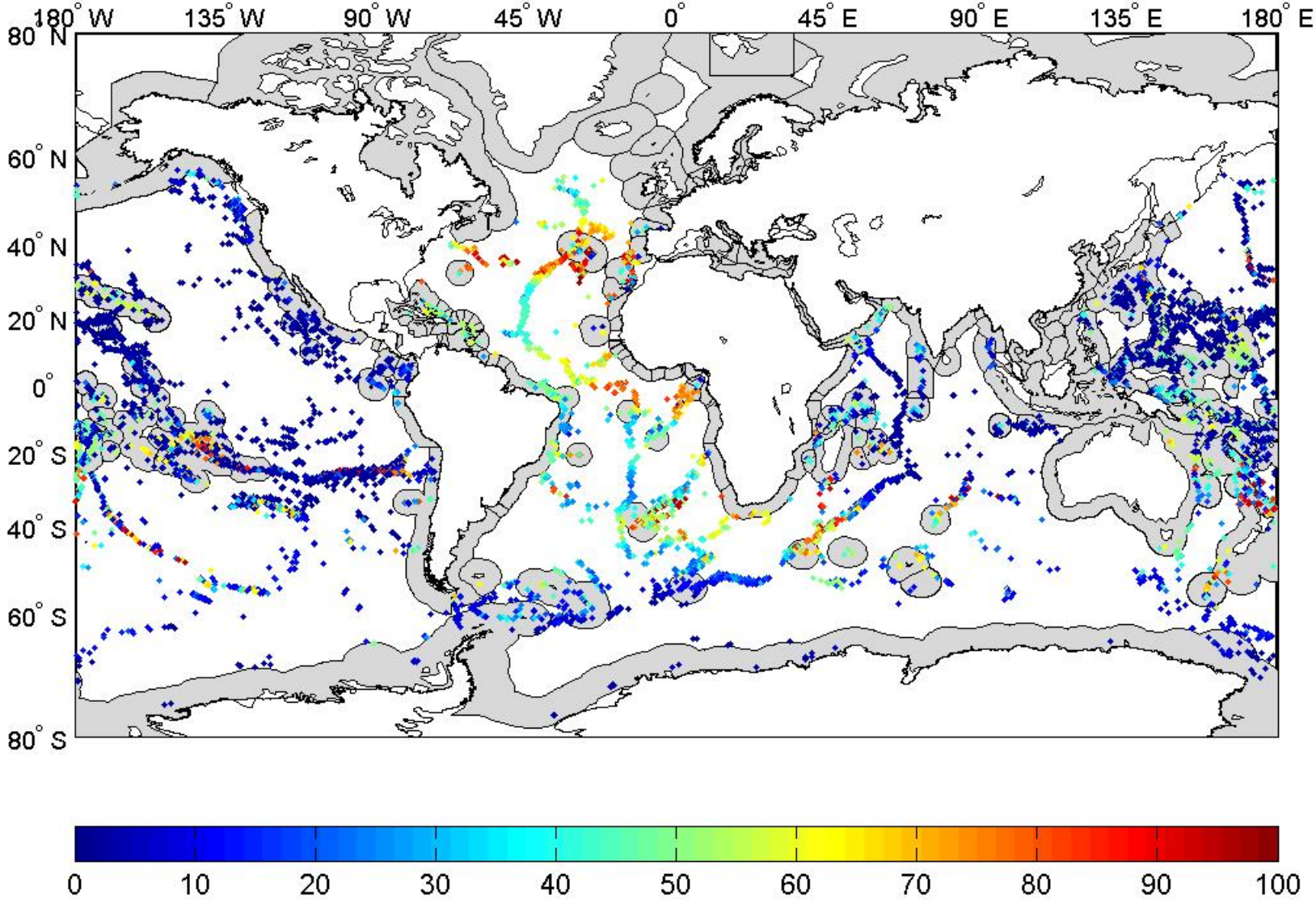
Predicting Seamount diversity



Percent predicted habitat suitability for Scleractinians corals on seamounts 1000m

Tittensor et al. Unpublished

Predicting Seamount diversity



Habitat suitability of known seamount summits

Diversity Program Findings

- Better knowledge of current populations
  - Spatial and temporal patterns of diversity and change
  - Diversity hotspots needing protection
- Better knowledge of impacts of industrial fishing and future population trends
  - Understand mechanisms of change
- Many marine populations and ecosystems declining

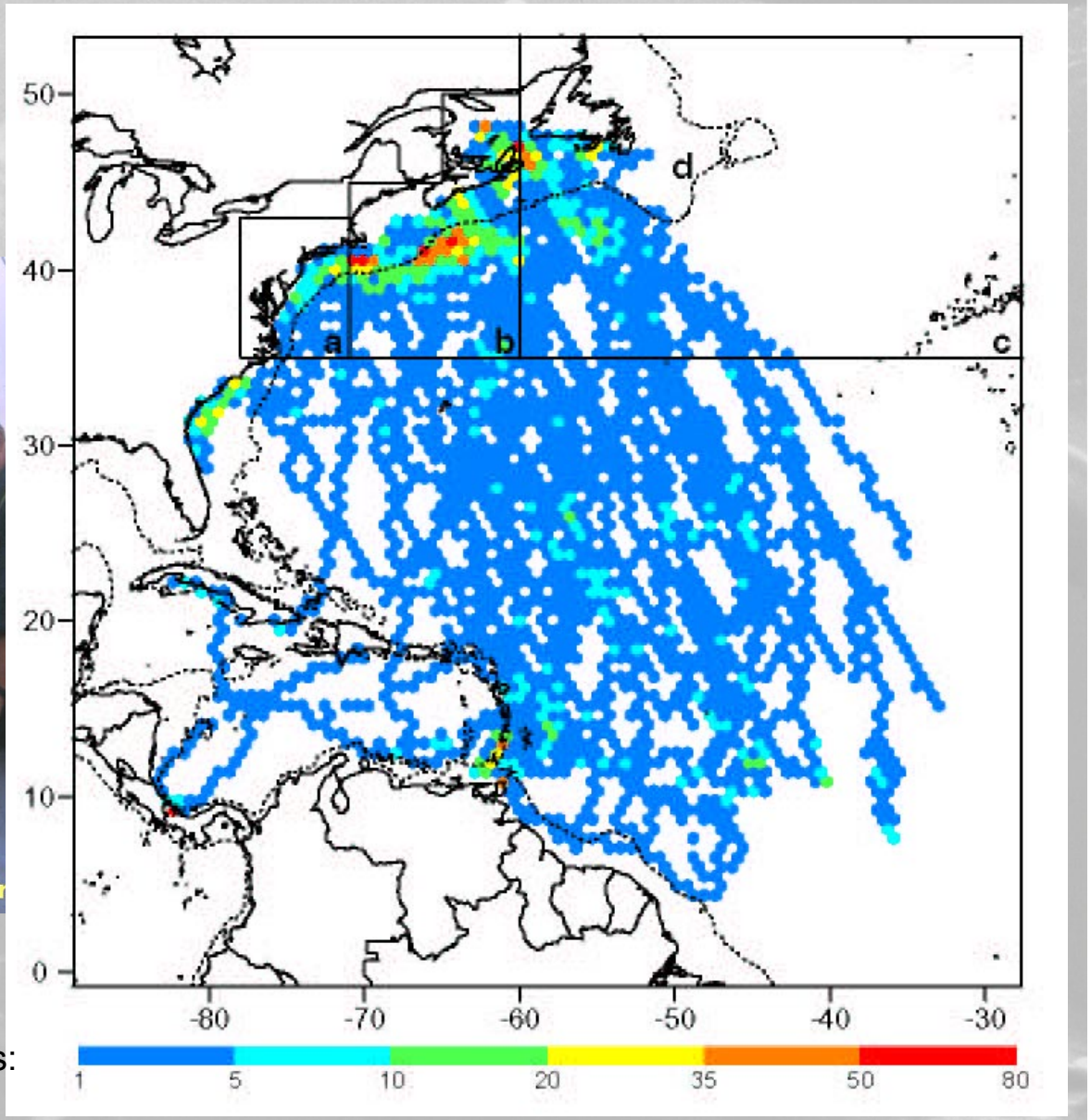
Part 2

Analyzing movement data

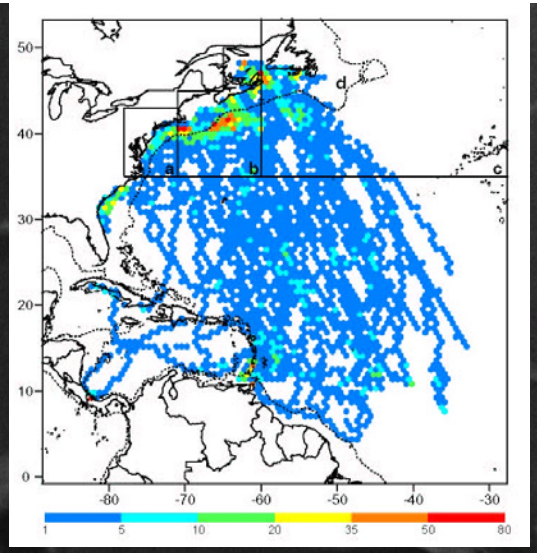
Identification of high-use areas and threats to leatherback turtles in northern waters

- **Data independent of fisheries**

No. of days spent in different areas:

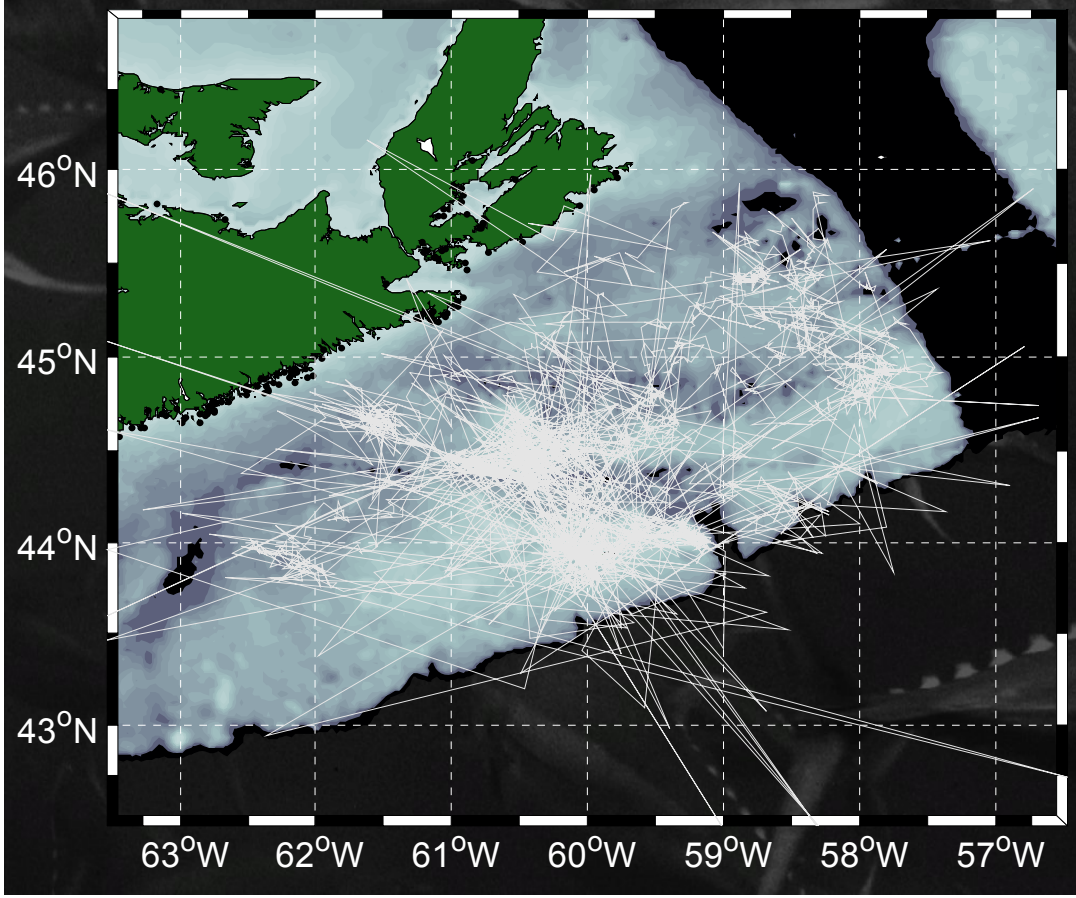


James, Ottensmeyer, Myers. Ecol. Letters (2005)



Why should we robustly analyze movement data?

Why isn't filtering good enough?



- Fine scale temporal patterns of distribution
- Seasonal & behavioural dynamics
- Directly model effect of oceanography on behaviour

State Space Models

Measurement Equation

- Relates imperfect observations to true position

- Estimate ARGOS error with ε

Error function

$$y_t = h(\alpha_t, \varepsilon_t)$$

observed location

true location

Transition Equation

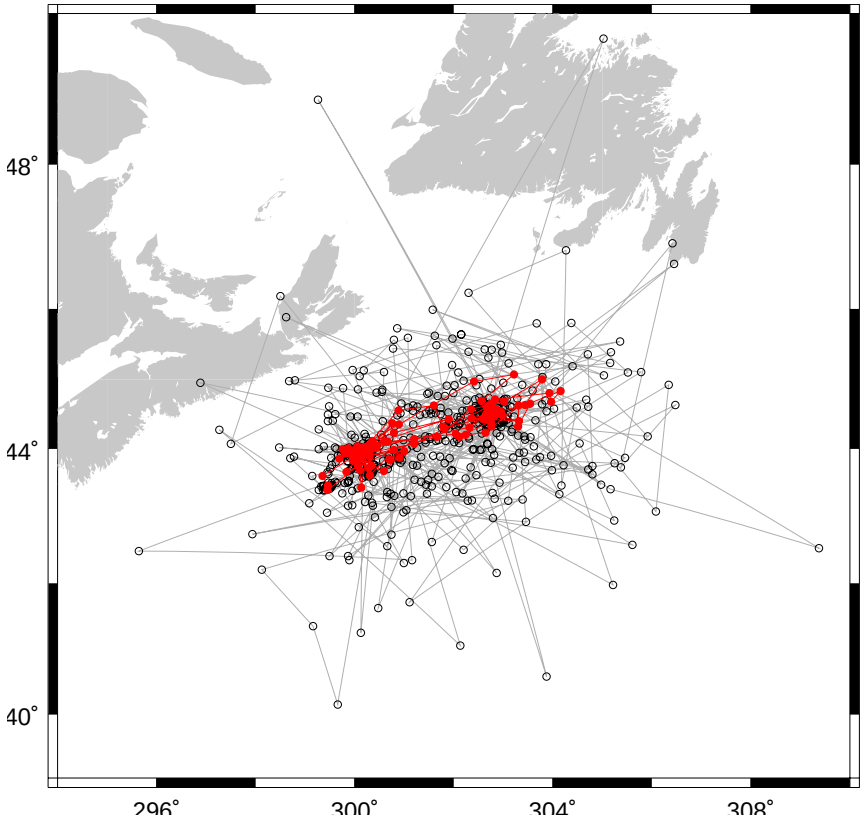
- Predicts next position from behavioral model

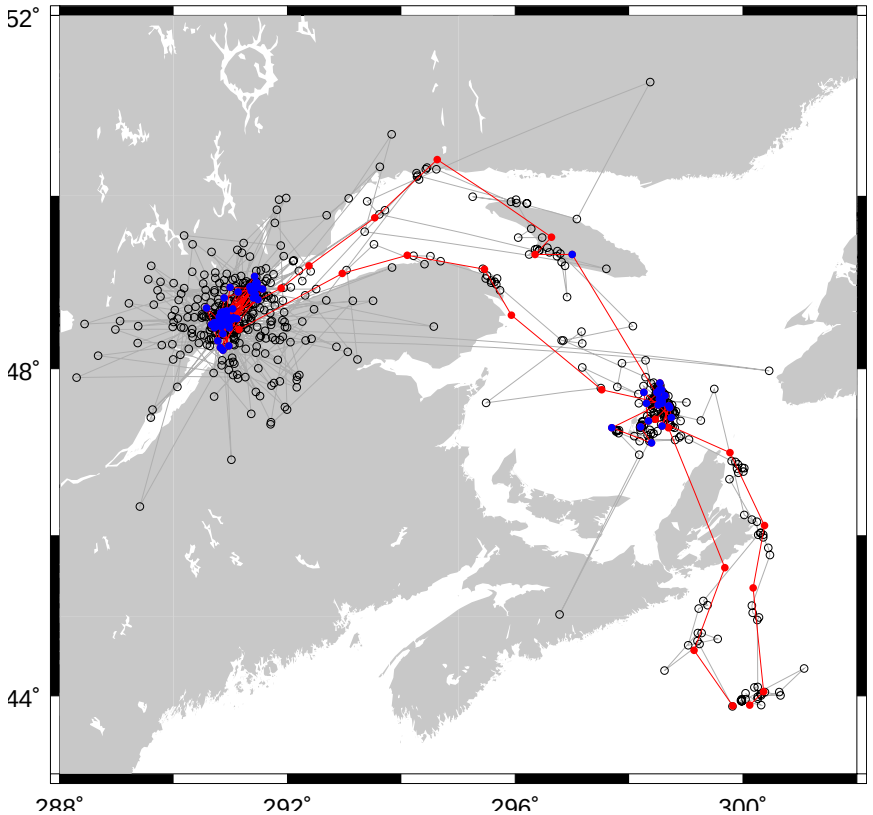
$$\alpha_t = f(\alpha_{t\text{-}1}, \eta_t; \gamma)$$

movement function

parameters

Some examples

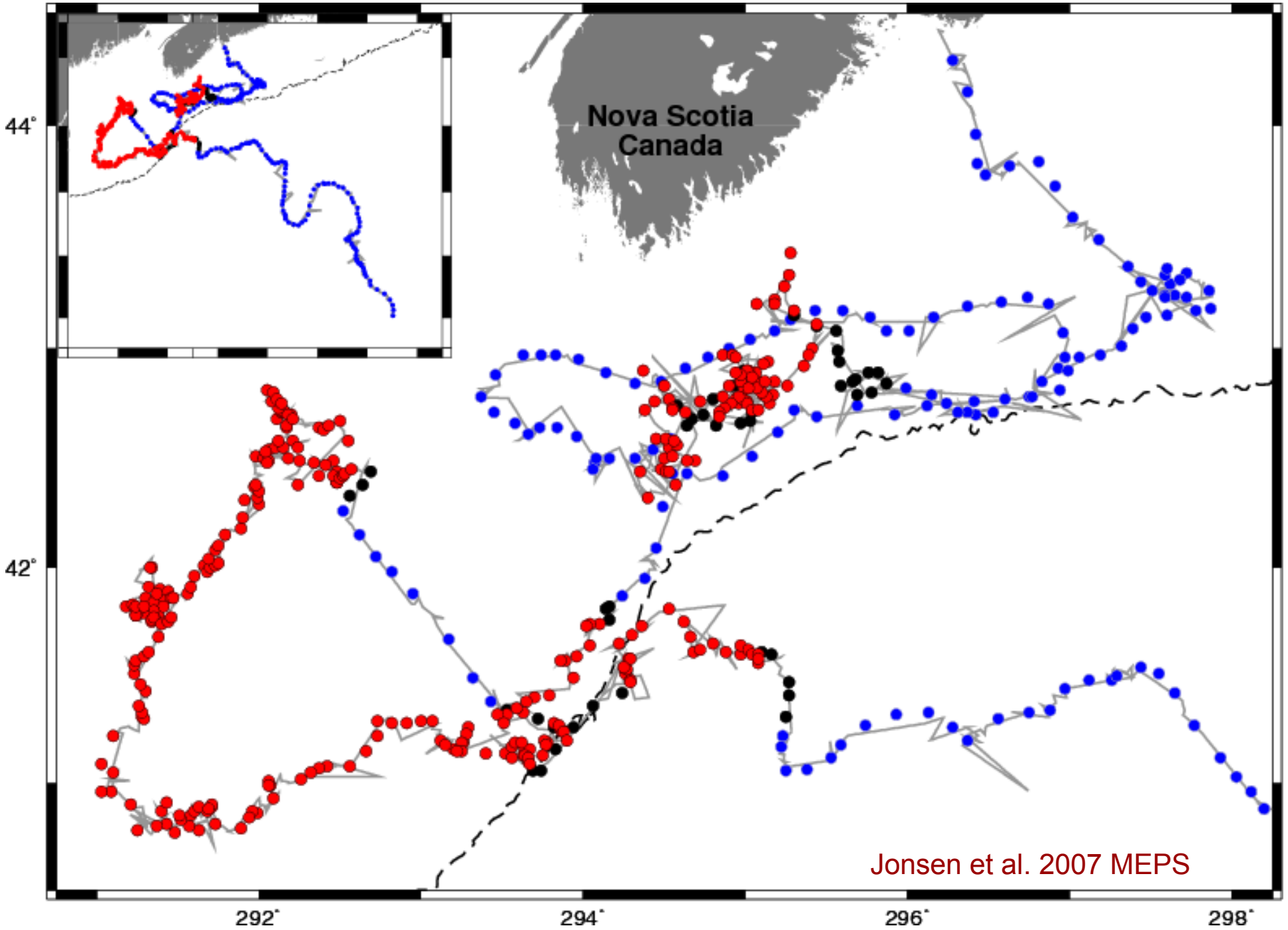


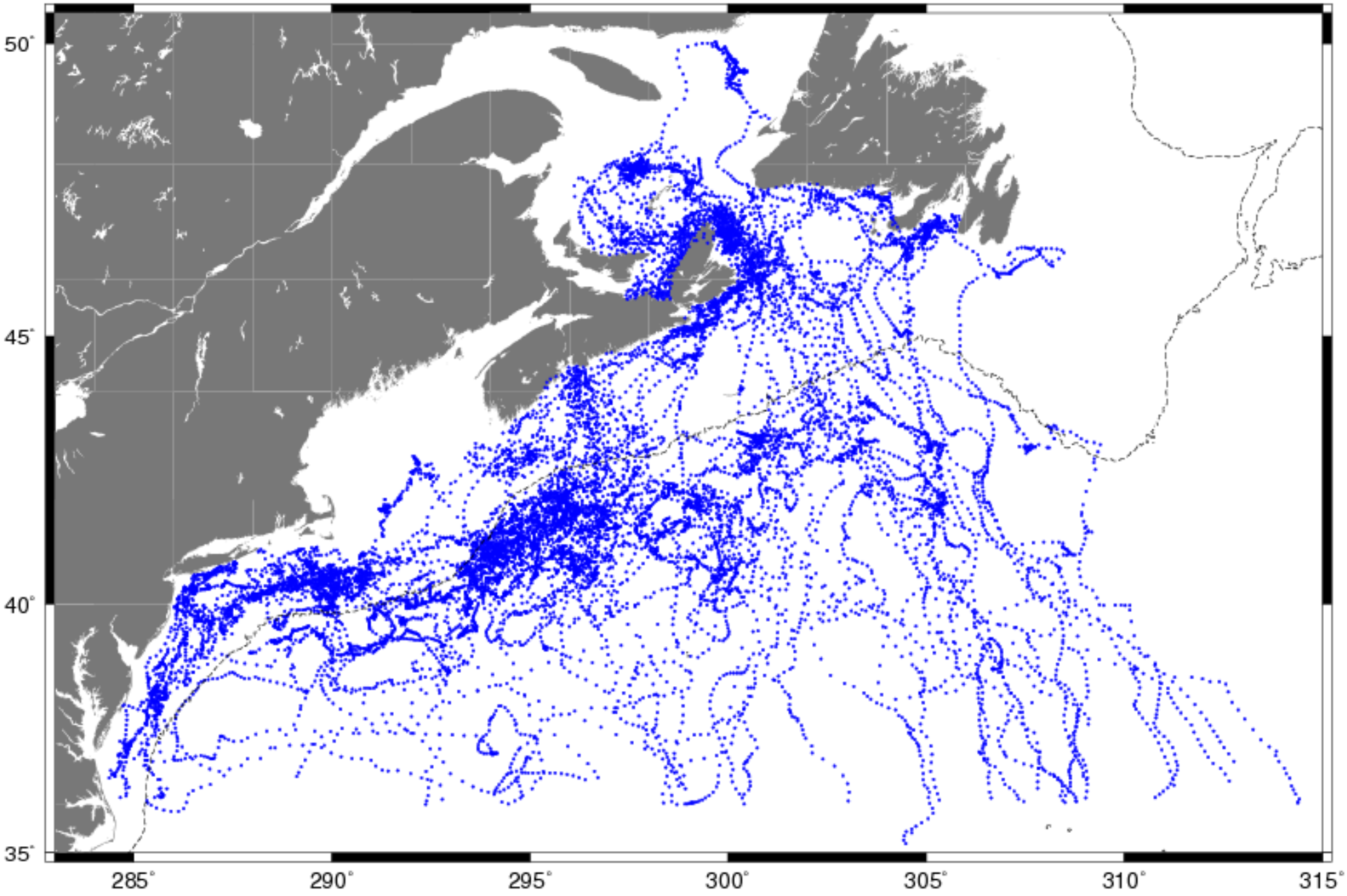


- Tracking data
- Model estimates for location
- Model estimates for foraging

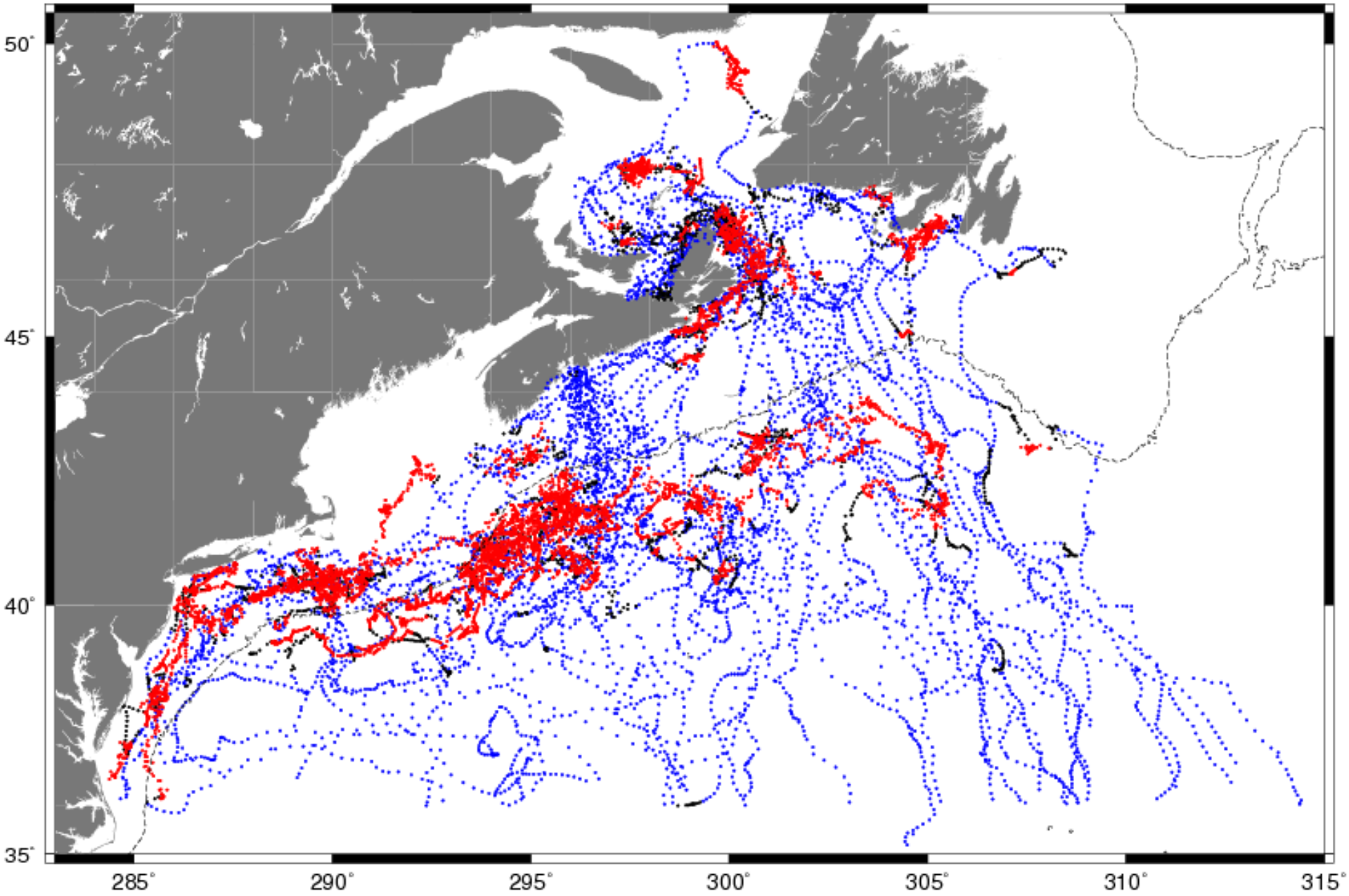
Grey seal location and behavior

Jonsen, Mills Flemming, Myers. Ecology (2005)


Nova Scotia
Canada
44°
42°
292°
294°
296°
298°
Jonsen et al. 2007 MEPS

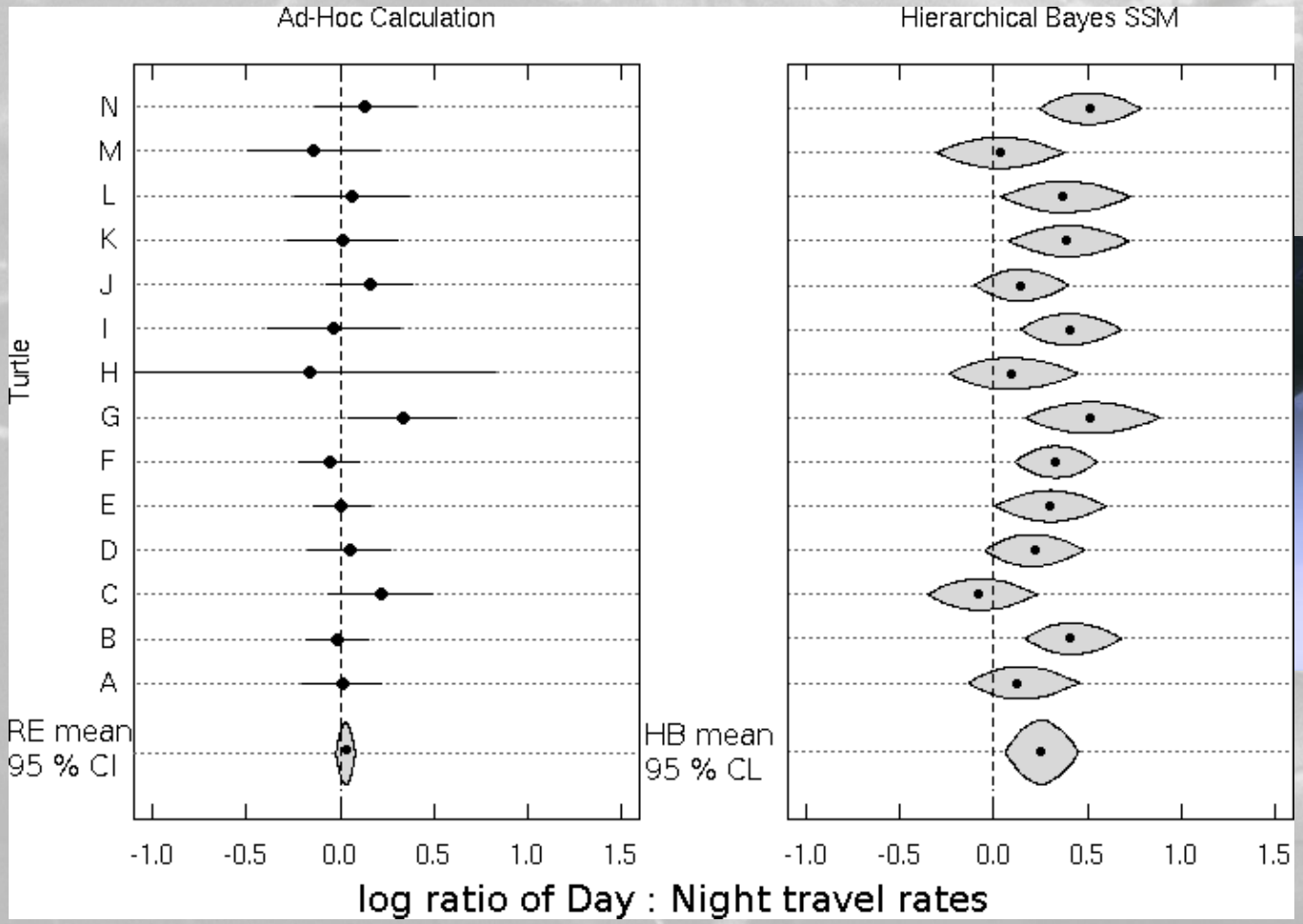


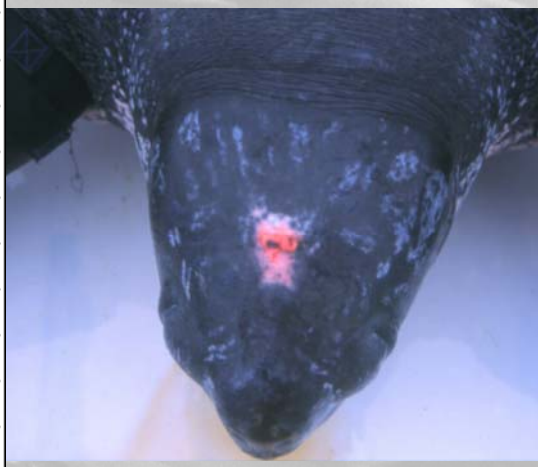
Jonsen et al. 2007 MEPS



Jonsen et al. 2007 MEPS

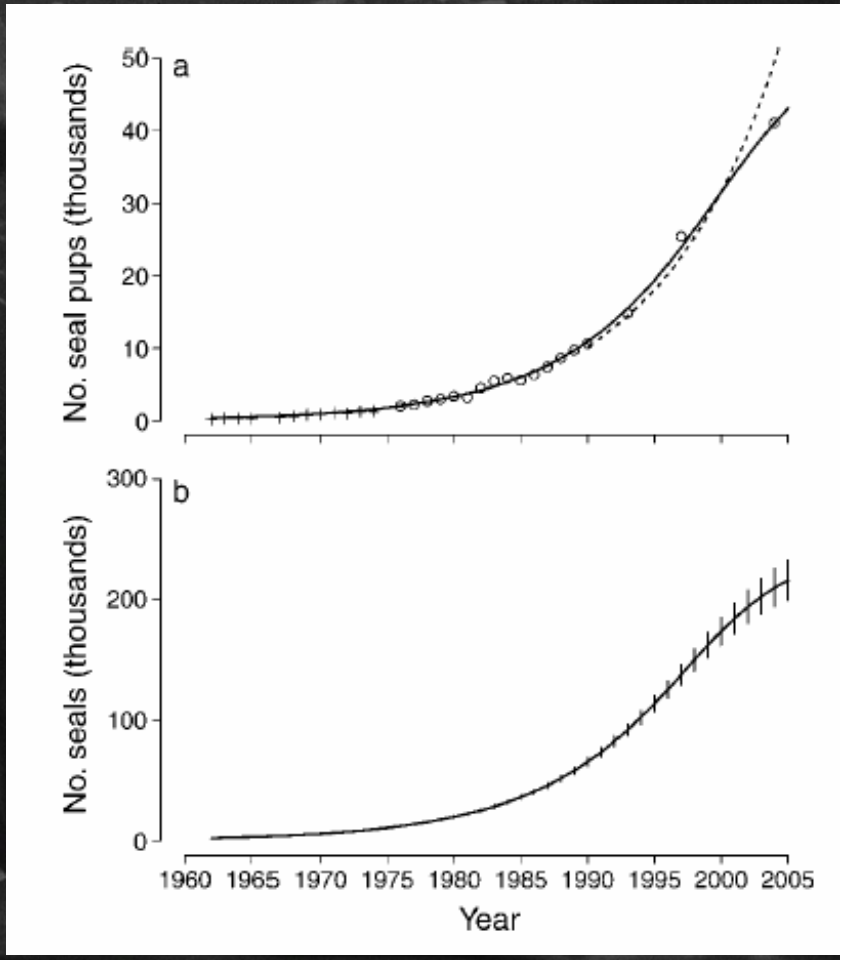
Understand biology & behaviour

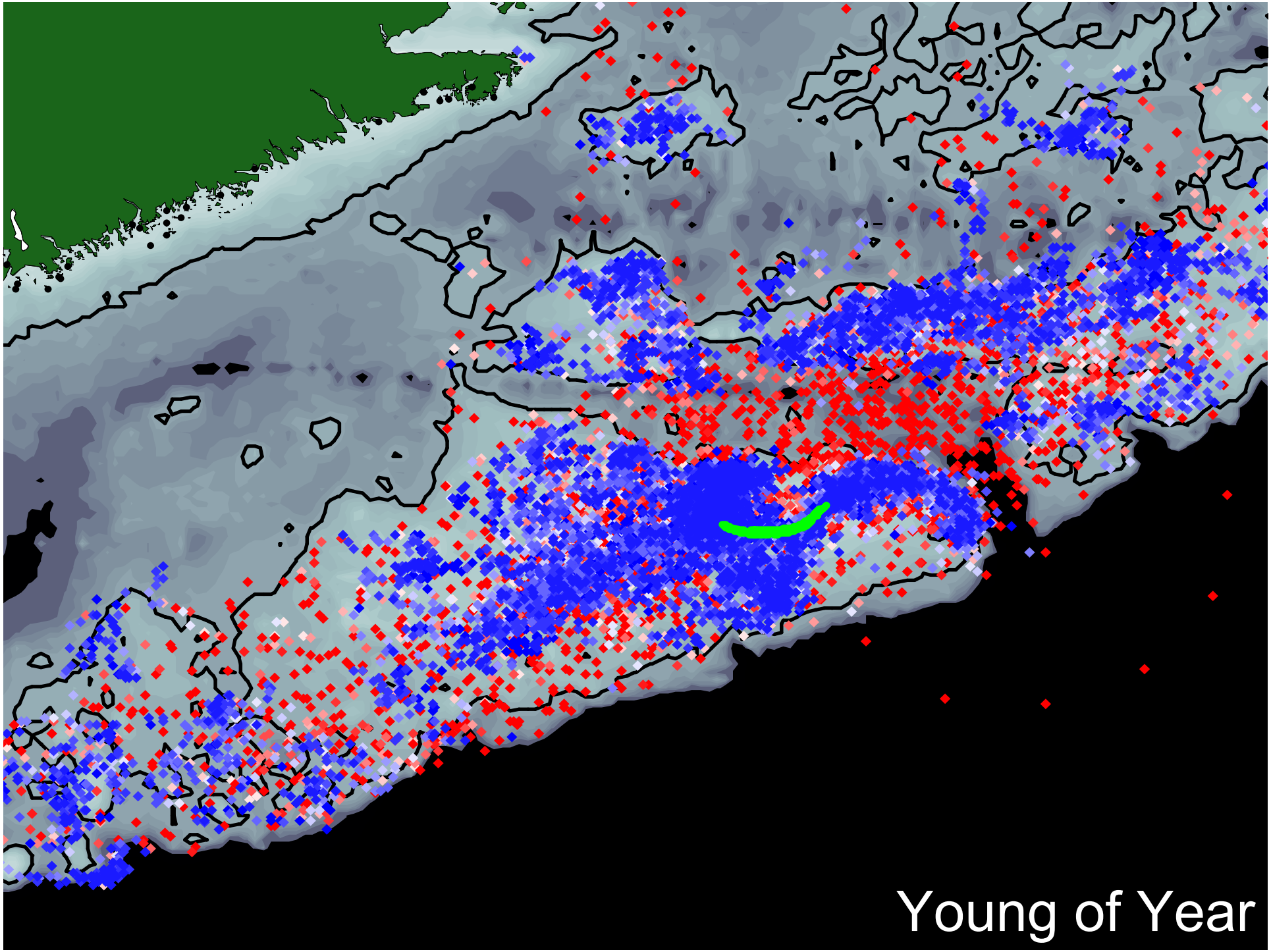


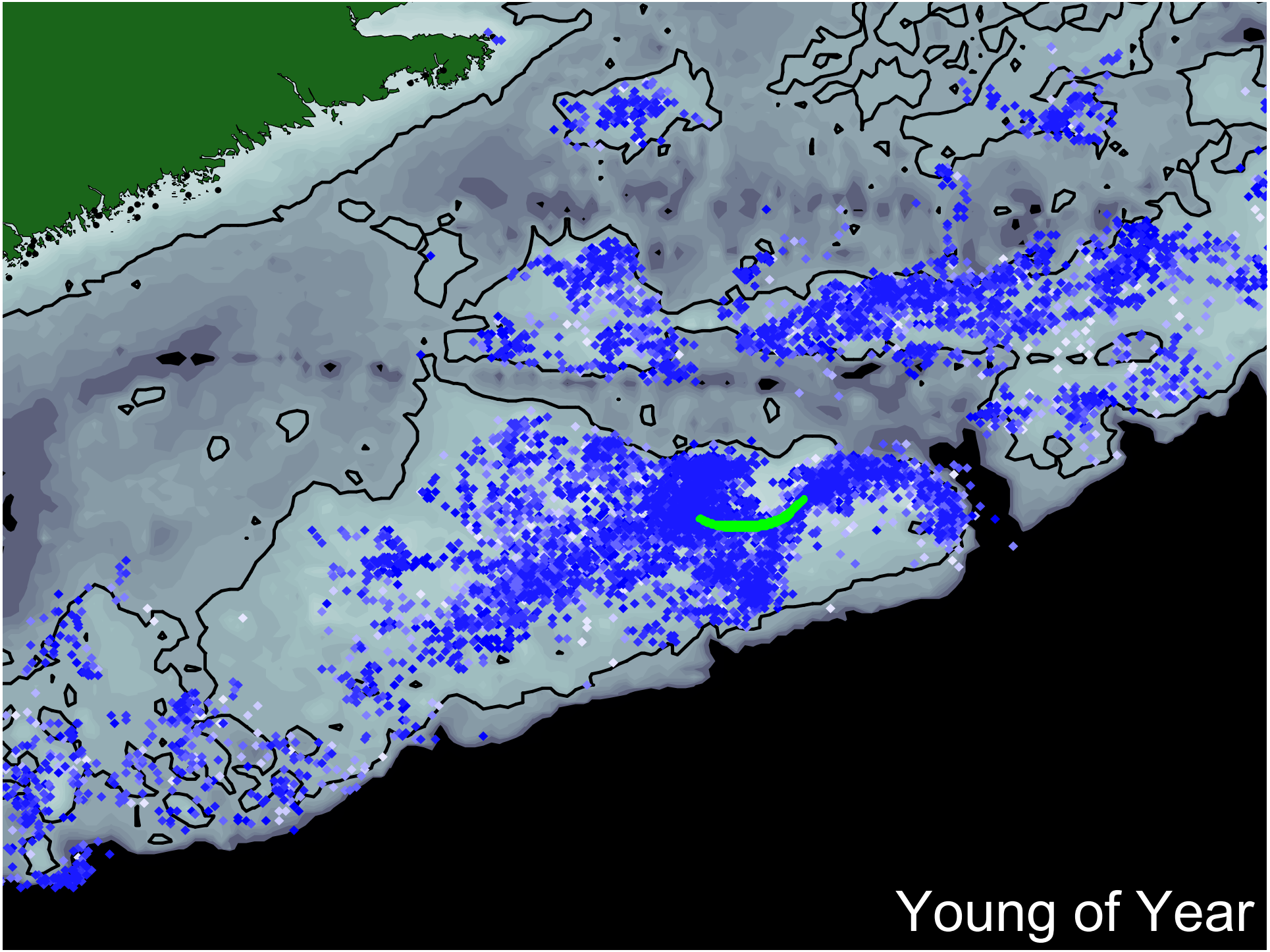


Jonsen et al. 2006 Journal of Animal Ecology 75

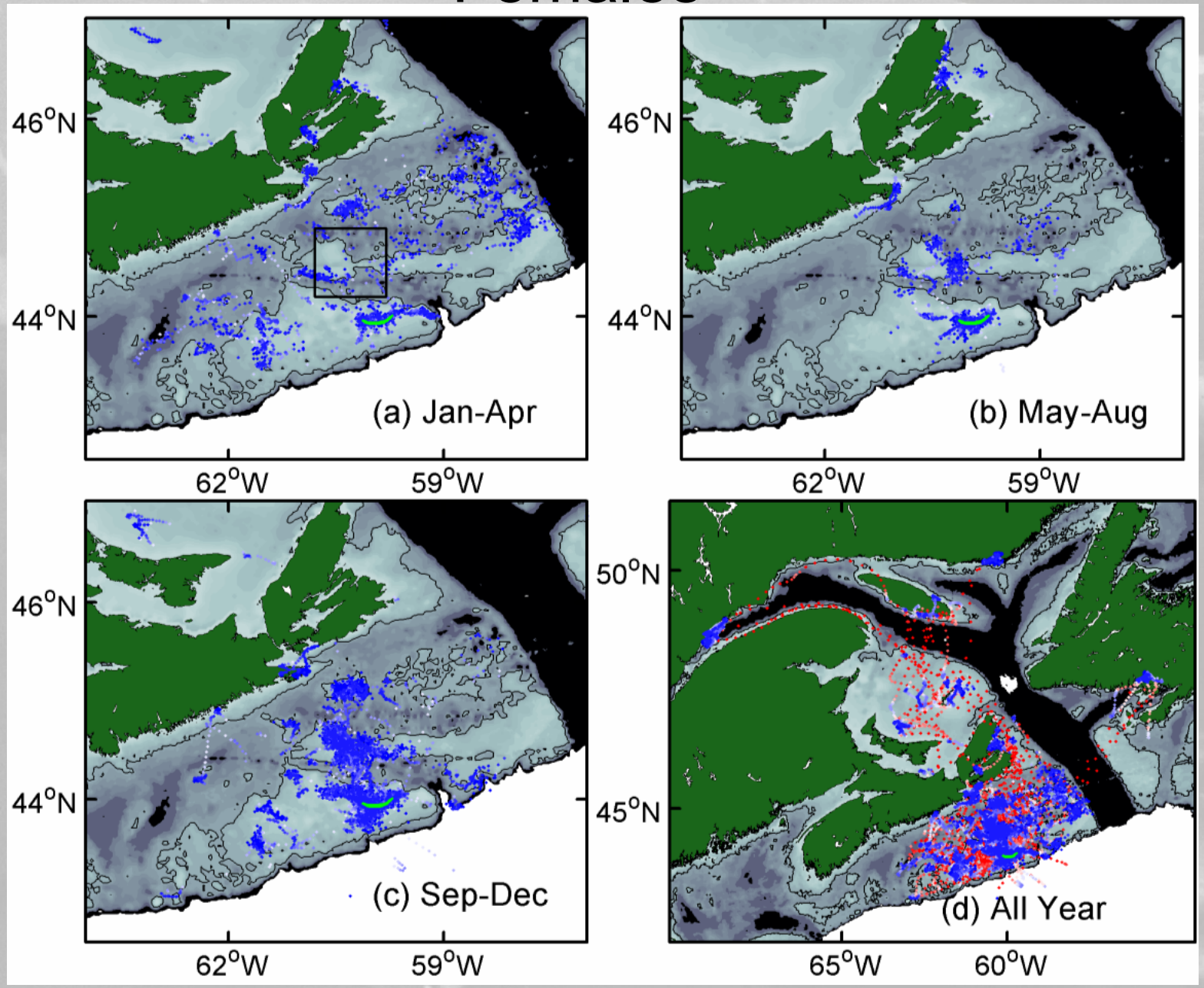
Grey Seal


a
No. seal pups (thousands)
50
40
30
20
10
0
b
No. seals (thousands)
300
200
100
0
1960 1965 1970 1975 1980 1985 1990 1995 2000 2005
Year


Young of Year

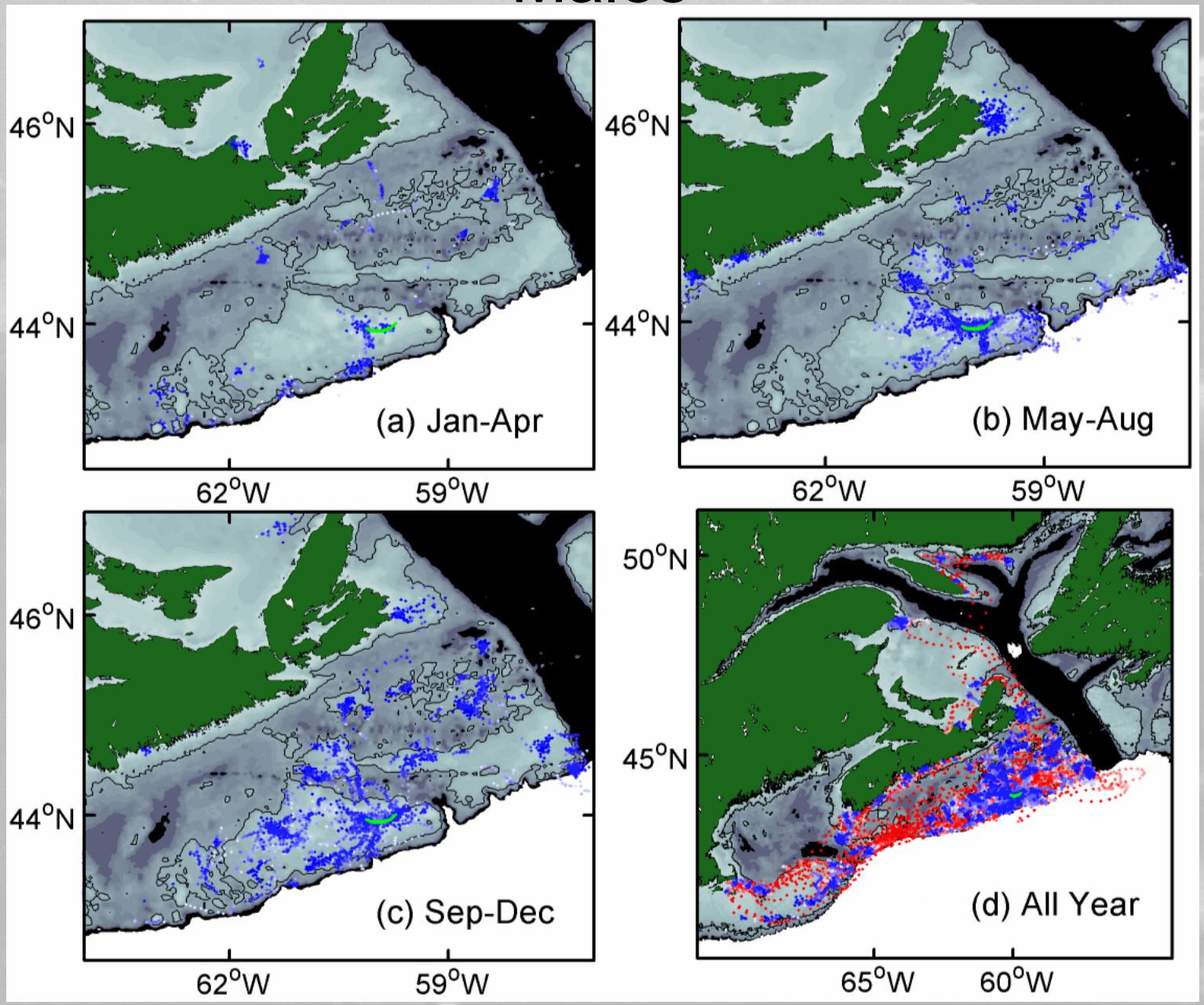

Young of Year

Females

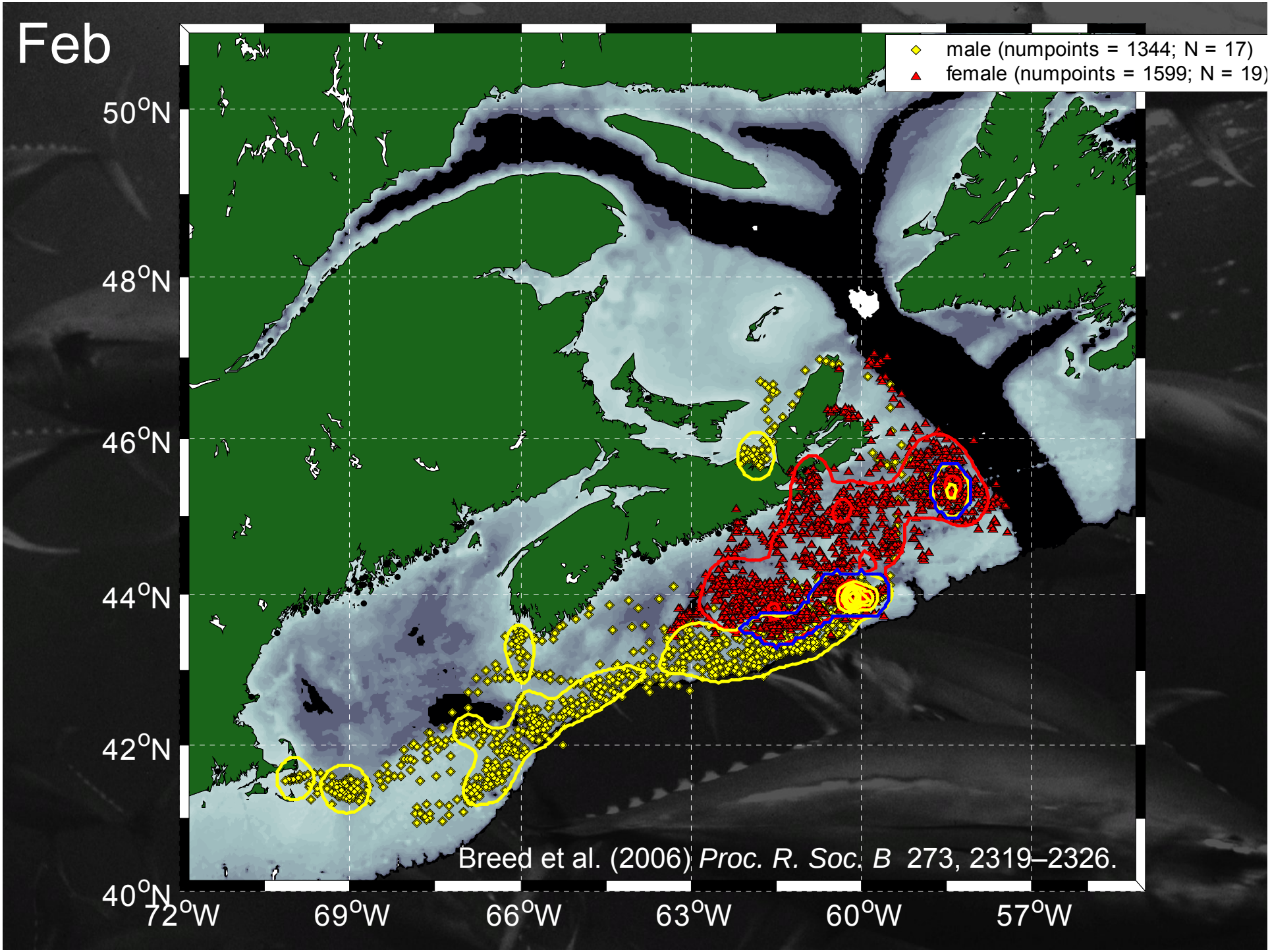


Breed et al. (2007) *Am. Nat. In revision*

Males



Breed et al. (2007) *Am. Nat. In revision*


Feb
male (numpoints = 1344; N = 17)
female (numpoints = 1599; N = 19)
50°N
48°N
46°N
44°N
42°N
40°N
72°W
69°W
66°W
63°W
60°W
57°W
Breed et al. (2006) Proc. R. Soc. B 273, 2319–2326.

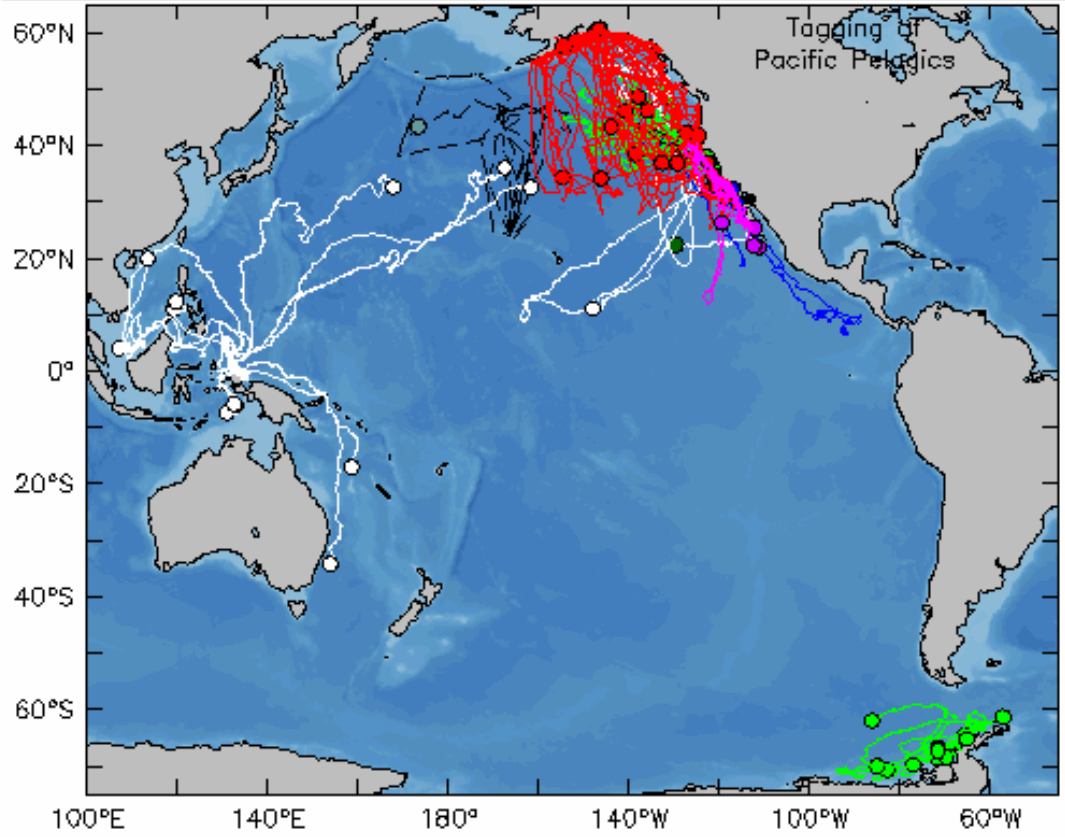
Tagging Of Pacific Pelagics

TOPP Near Real-Time Animal Tracks

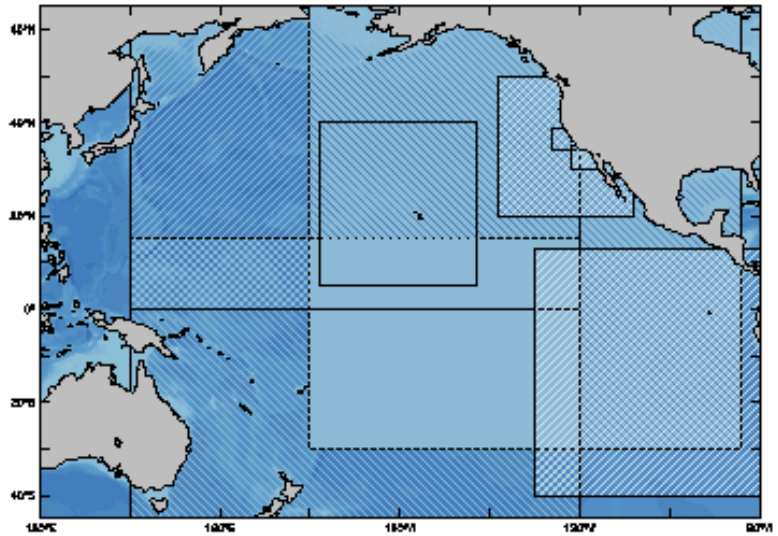
CENSUS OF MARINE LIFE

Tags reporting within the last 60 days

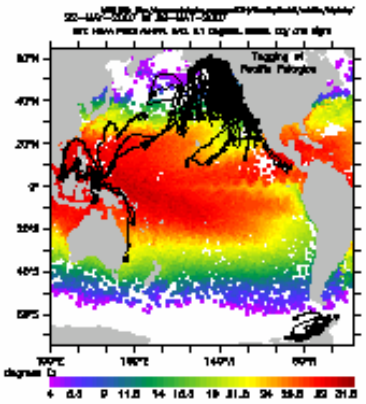
Roll mouse over end points to see animal and tag info. Click on end points or pttno in table for larger image



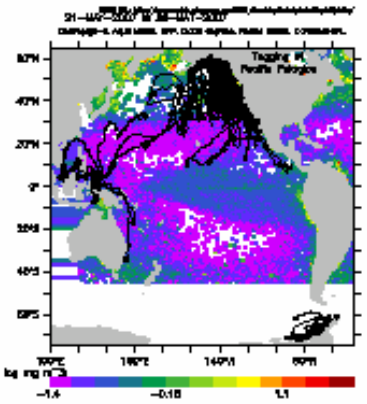
This tag information is for viewing only.
Please obtain **permission to use**



Sea Surface Temperature

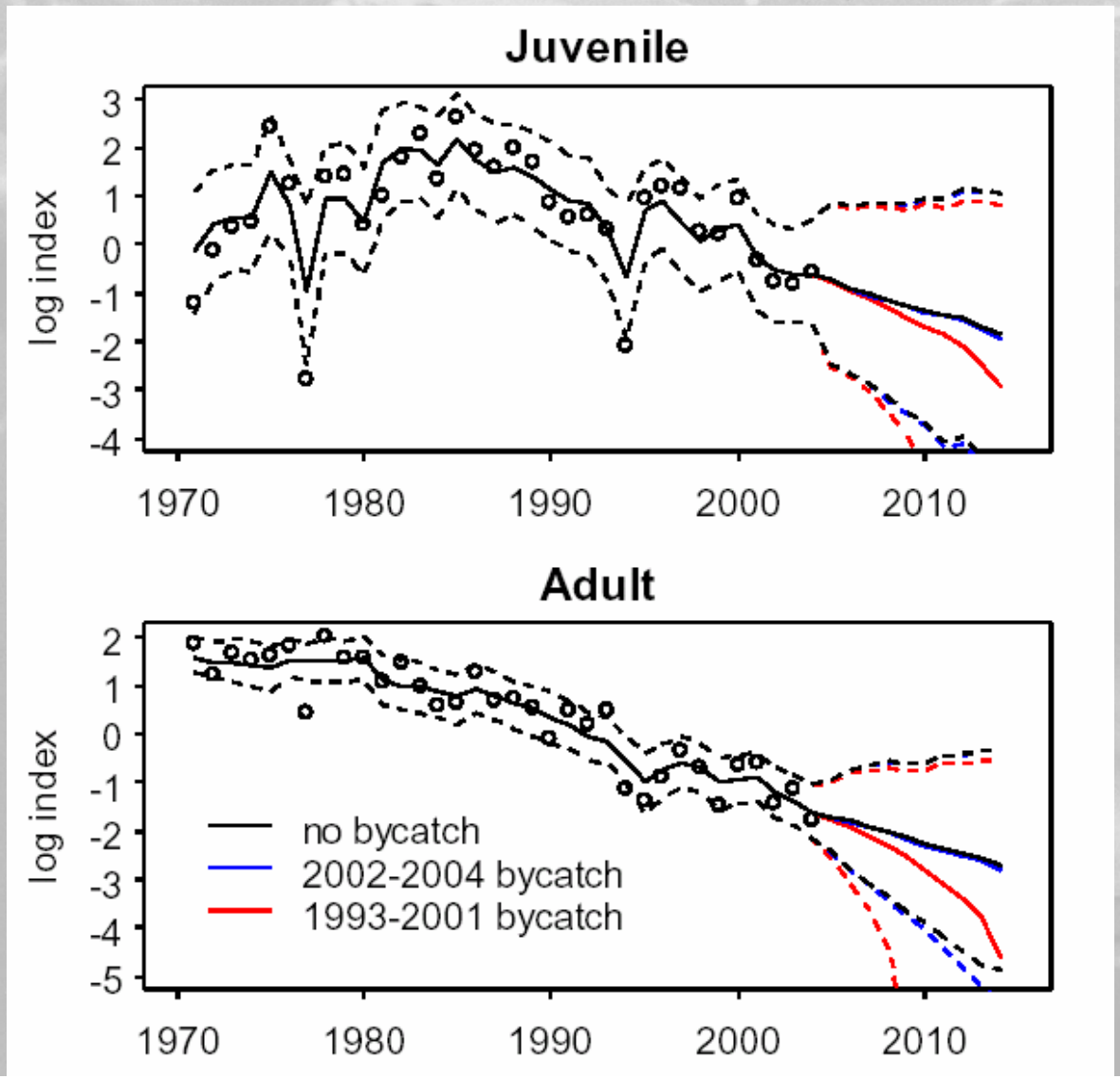


Chlorophyll-*a*



Winter skate population projections

Swain, Jonsen, and Myers 2006, DFO Can.



Two Questions:

How does this work contribute to the conservation and management of coastal and living marine resources and biodiversity?

- Defined worldwide population and diversity trends
- Measured effectiveness of MPAs
- Identify regions of high biodiversity
- Refined habitat needs and behaviour of large pelagics

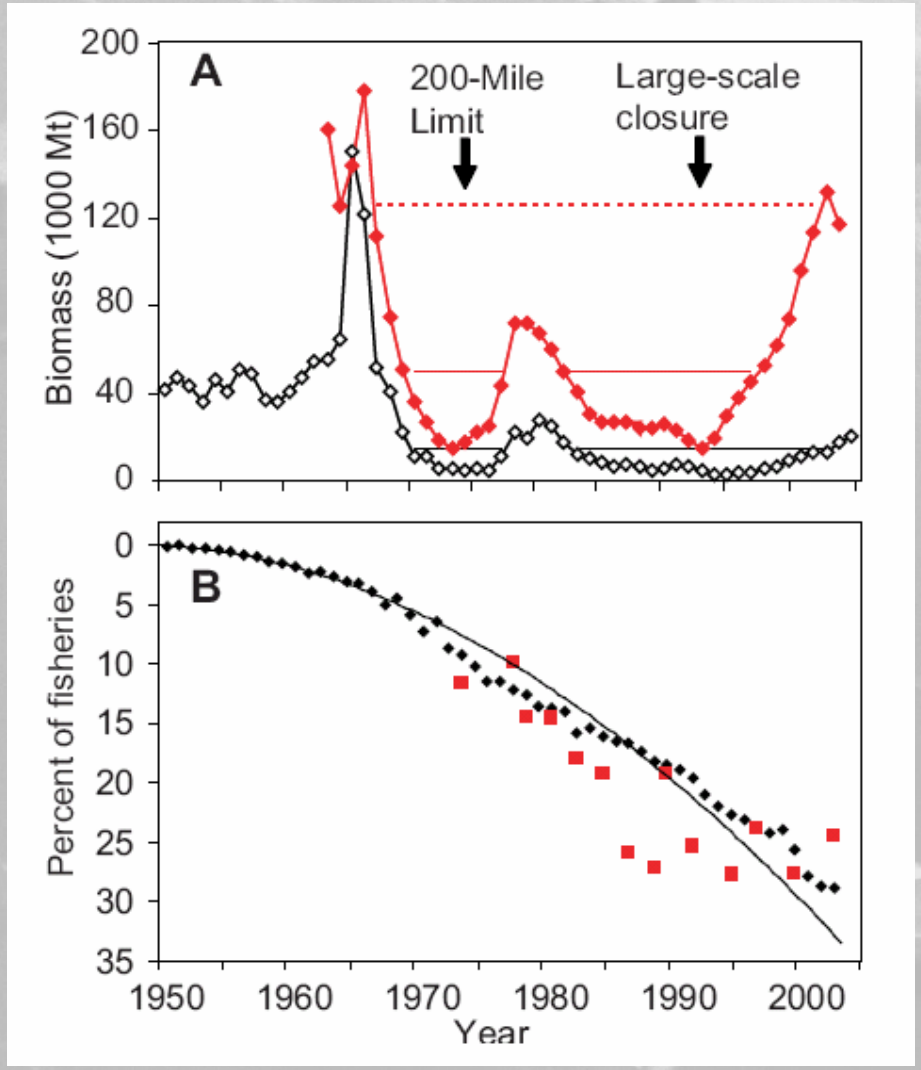
What would be required to continue FMAP efforts?

- Open access to data
- Salaries

Collaborators & Funding

- Trevor Davies
- Julia Baum
- Chris Field
- Joanna Mills Flemming
- Mike James
- Ransom Myers
- Don Bowen
- Marty Leonard
- Wade Blanchard
- Shelly Lang
- Debbie Austin
- Jim McMillan
- Derek Tittensor
- Scott Sherril-Mix
- Dan Ricard

- The Sloan Foundation
- Census of Marine Life
- Future of Marine Animal Populations
- NSERC
- National Program on Complex Data Structures
- DFO Canada
- Pew Charitable Trusts
- Lenfest Ocean Program
- NMFS
- ESRF



Comparison of fisheries catch and biomass trends. (**A**) Georges Bank haddock (*Melanogrammus aeglefinus*) catches (white diamonds) and spawning stock biomass (red diamonds). Black line indicates collapsed status based on 90% reduction in catches; red solid line indicates collapse based on 90% reduction in biomass; and red dotted line indicates overfished status as defined by NOAA/NMFS. (**B**) Global fisheries trends. Shown is the proportion of fisheries where catches in a given year declined 90% or more below the historic maximum (black diamonds and trend line from our paper), and those that have been assessed by FAO as overfished, depleted, or recovering from depletion [red squares, from (*5*)]. The latter are only a subset of all stocks, i.e., those that have biomass estimates available.

State Space Models

Maximize likelihood
to estimate model parameters
γ

Error function

$$y_t = h(\alpha_t, \varepsilon_t)$$

observed location

true location

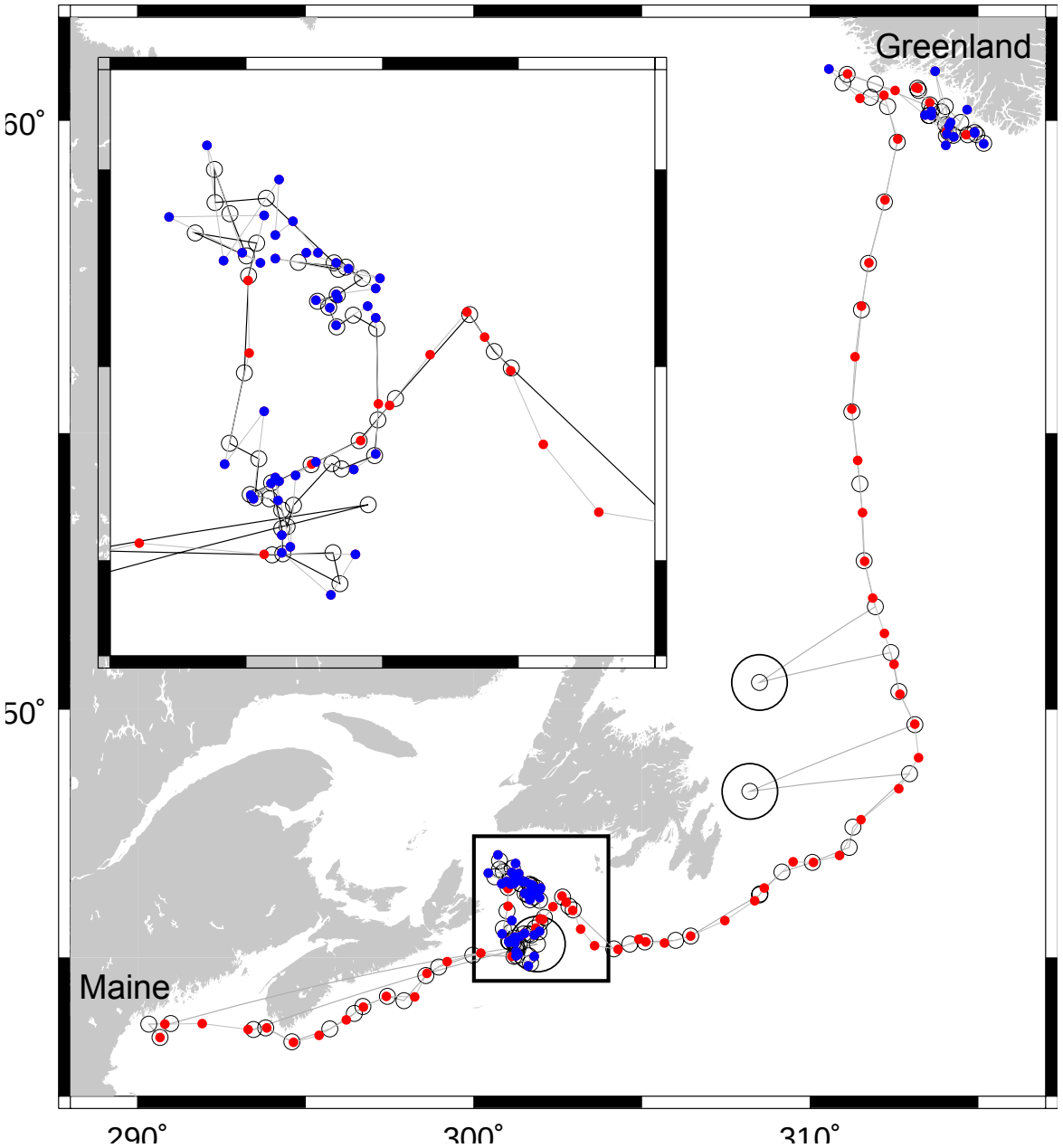
Use Markov Chain
Monte Carlo methods
in WinBugs

$$\alpha_t = f(\alpha_{t-1}, \eta_t; \gamma)$$

movement function

parameters

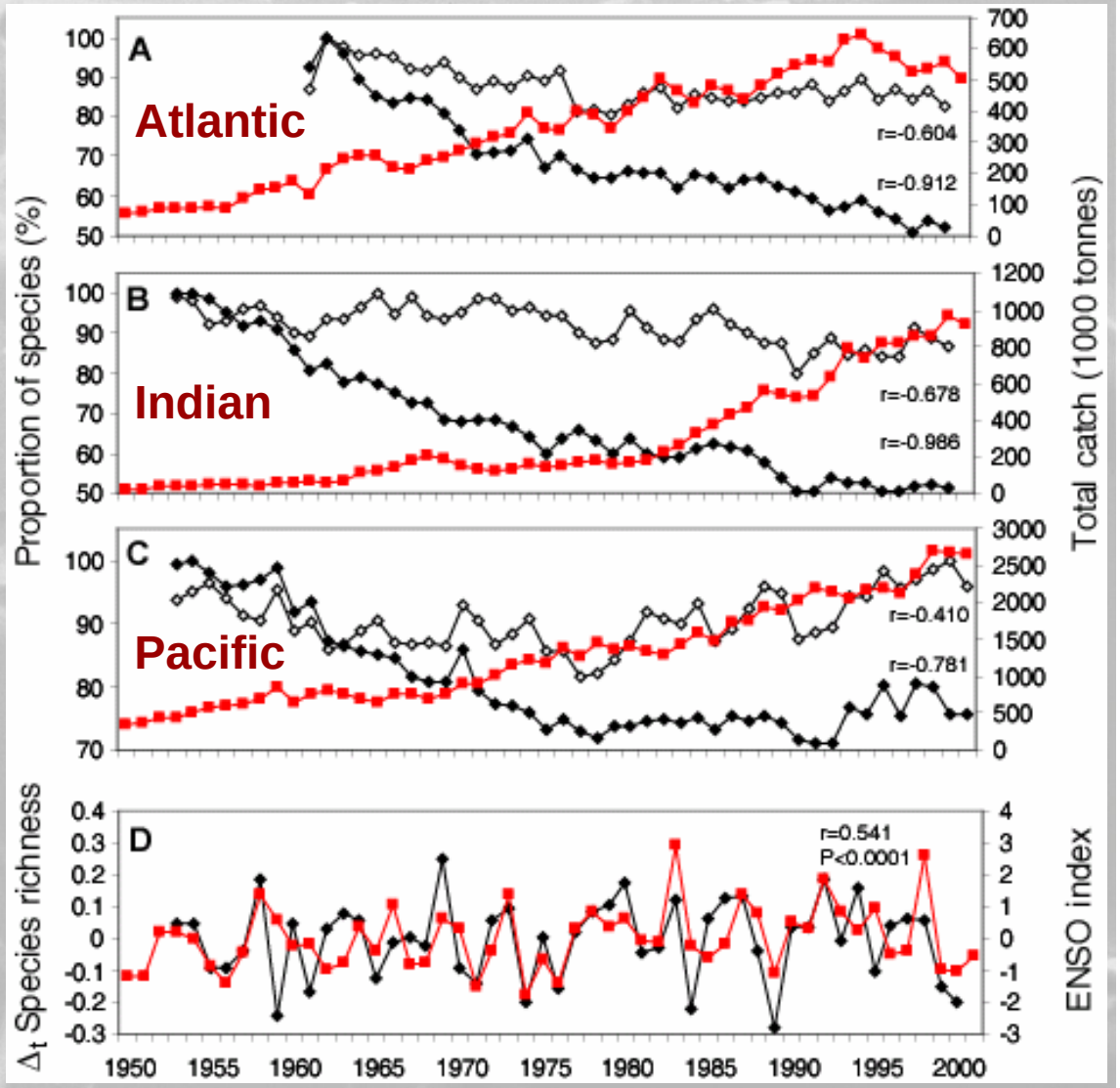
Hooded seal foraging and migration



Jonsen, Mills Flemming, Myers. Ecology (2005)

Global decline in diversity last 50 years

- Decreasing diversity:
  - sp. richness (white)
  - sp. density (black)
- Increasing catches (red)
- Long-term decline linked to fishing
- Annual variability linked to climatic changes



Worm et al. 2005. Science: 309:1365-1369